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Radiation Hardness Assured Device Development
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Radiation Hardness Assured supplements to four military device detail specifications have been prepared using radiation characterization data on the six device types included in these specifications. The four RHA specifications (M38510/101, S19500/323, S19500/350, and S19500/355) include provisions for six part types; the 741A, LM101A, LM108A, 2N3251A, 2N3868, and the 2N2920.

Group D/E end-points and post-irradiation characteristics are calculated from these data. The methodology for performing these calculations is detailed such that future RHA devices can be developed utilizing this approach.

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# SECTION 1

## INTRODUCTION AND BACKGROUND

### 1.1      INTRODUCTION.

This report summarizes the work performed under HDL contract No. DAAL02-87-P-4084. The major output of this eight-month effort includes preliminary and final drafts of four proposed radiation hardness assured (RHA) military device specification amendments. The four RHA specifications (M38510/101, S19500/323, S19500/350, and S19500/355) include provisions for six part types: the 741A, LM101A, LM108A, 2N3251A, 2N3868, and 2N2920. The statistical analyses and methodology utilized for the development of these draft RHA mil spec amendments are presented in section 2, along with the RHA characterization data, data analyses, and RHA end-point limits and post-irradiation characteristics developed for these devices. Section 3 reports additional effort in support of the DNA Advisory Group on Hardness Assured Specifications and Standards in the form of recommended draft revisions of RHA device specifications and standards. Recommendations for the development of additional RHA device specifications are also included in this section. The draft RHA amendments for the devices listed above are included in this report as attachments in Appendix A.

### 1.2      BACKGROUND.

"Hardness assured" refers to devices which have met specific radiation hardness requirements, designed to assure a defined level of post-irradiation performance. A plan for incorporation of such requirements into the military specification system for semiconductor devices has been developed, and the specific changes have been incorporated into the general specifications for semiconductor devices (MIL-S-19500) and for microcircuits (MIL-M-38510), as well as the test standards on which these specifications rely (MIL-STD-750 and MIL-STD-883). Details of these modifications have been reported previously (Refs. 1-3).

The modifications made to MIL-M-38510 and MIL-S-19500 included both qualification (Qual) and quality conformance inspection (QCI) requirements for RHA devices. A series of radiation levels and requirements which include new letter designations and part markings, general sampling plans for radiation testing, and unique lot traceability requirements for hardness assurance are also defined in these specifications. These new requirements reflect the cooperative efforts of the NASA/Space Division Space Parts Working Group (SPWG) Hardness Assurance Subcommittee, Defense Nuclear Agency and the DNA Hardness Assurance Advisory Group, Aerospace Corporation, NASA - Goddard, Harry Diamond Laboratories, Rome Air Development Center, Naval Research Laboratory, Defense Electronic Supply Center, NAVELEX, Naval Weapon

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Support Center, Air Force Weapon Lab, Jet Propulsion Lab, and other interested companies, individuals and agencies.

In this earlier work, four new part labels were proposed, corresponding to radiation levels stratified for total dose hardness with minimum neutron fluence levels. The radiation levels corresponding to the part labels, M, D, R, and H are shown in table 1. The levels are independent of the reliability classes. This approach represents the necessary compromise between part type proliferation, anticipated cost impacts, and system requirements. It is based upon the use of existing QPL military specification devices as a source of high reliability parts for hardened system applications. Additional hardness characteristics which are presently under consideration for inclusion in detail specifications include transient dose rate and single-event upset specifications.

The specifications cover only room temperature ($25^{\circ}$C nominal) operations. For applications requiring radiation hardness assurance at temperatures other than $25^{\circ}$C ambient, reference can be made to the Military Handbooks for neutron and total dose hardness assurance guidelines (Refs. 4 and 5) and other guideline documents.

Table 1.    Hardness Assurance Levels for RHA Devices

| PART DESIGNATION | HARDNESS ASSURANCE LEVELS | |
| --- | --- | --- |
| | TOTAL DOSE | NEUTRONS* |
| M | 3000 RAD(SI) (30 GY(Si)) | $2 \times 10^{12}$ n/cm2 |
| D | $10^4$ RAD (SI) | $2 \times 10^{12}$ n/cm$^2$ |
| R | $10^5$ RAD (Si) | $2 \times 10^{12}$ n/cm$^2$ |
| H | $10^6$ RAD (SI) | $2 \times 10^{12}$ n/cm$^2$ |

*1-MEV SILICON DAMAGE EQUIVALENT

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# SECTION 2

## DEVELOPMENT OF RHA DEVICE SPECIFICATIONS

### 2.1    INTRODUCTION

The general methodology for preparation of RHA device specifications has been reported previously (Ref. 1-3). A summary of the some of the more important issues for the development of RHA devices is included in Section 3 as a draft input to a Military guideline document for the preparation of RHA specifications. The calculations, performed to derive the specific values in the RHA detail specification supplements in Appendix A, followed the basic methodology prescribed in these reports, and are included in this section of this report. The most significant addition or modification to an existing (i.e.,non-RHA) device detail specification is the table of post-irradiation parameters (functional and parametric values) which the RHA device must satisfy for qualification or quality conformance inspection. These parameters are termed the post-irradiation "end-points" or "end-point limits" and are the specific pass/fail test limits that the RHA Qual and QCI test samples must pass for the lot to be acceptable.

The approach followed include the collection of radiation characterization data, either by the use of existing data or the generation of new radiation data, performing some type of statistical analysis for projecting these data to future lots to be procured, and incorporating these values into new detail specifications, new amendments, or supplements to amendments. The devices included in this effort are mature device types for which non-RHA detail specifications and amendments currently exist. The RHA provisions for these devices are in the form of draft RHA supplements to the latest amendments to these detail specifications.

The steps followed in collecting and analyzing radiation characterization data for the six part types (741A, LM101A, LM108A, 2N3251A, 2N3868, and 2N2920) are reported in this section. Details of the statistical methodology followed for establishing ground-rules for RHA QCI requirements are detailed in this section since this methodology serves as the starting basis for the RHA end-point calculations.

### 2.2    STATISTICAL ANALYSES OF RHA DATA

### 2.2.2    Multi-Lot Statistical Limit

The statistical approach described in this work is an extension of the tolerance-interval estimate method, extended for multiple lot procurement such as used in the military device

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specification system. It is assumed that lot sample acceptance testing by attribute testing [i.e., pass/fail testing such as used in lot tolerance percent defective (LTPD) tests] is mandated because of cost-effectiveness considerations. Statistics from individual lots are combined so that one can estimate the potential impact of hardness assurance on lot "yields." The method allows for the situation where lot-to-lot variations are greater or equal to the variations over individual lots, and, though there are some problems with its accuracy, can be applied to the inverse as well.

The basic approach (Refs. 3,6) is to utilize multiple-lot sample data to compute reasonable parameter failure limits for pass/fail lot acceptance testing. These failure limits can then be used as design limits in circuit applications provided suitable caution is used to account for the statistical basis of these limits. Lot sample data are assumed to be in the form of means and standard deviations of radiation-induced parameter values or parameter delta values (i.e., the difference between post-irradiation and pre-irradiation parameter values). Sample sizes are assumed to be small for cost efficiency reasons (typically on the order of 5 to 15). The basic problem then is to combine the means and standard deviations for lot sample data of various small sample sizes in such a way as to define a "failure" limit or end-point limit from these data.

Lot quality for QCI is typically verified by performing a radiation test on a sample of parts with the requirement that no more that a certain number of failures may occur for the lot to meet the maximum percent defective requirement. The requirement for class B is that 11 parts be tested for neutrons and 22 parts for total dose from each inspection lot with no failures allowed (an 11/0 test which corresponds to an LTPD of 20 per cent). Class S RHA sampling is per wafer (2/0 for LSI and 4/0 for MSI/SSI devices). End-point limits for each important device parameter can then be determined based on the criterion that a given fraction, $P_a$, of future lots will pass an 11/0 test (or 22/0) with 90 per cent confidence. The analysis here is performed with the usual assumptions that the parameters follow normal or log normal population distributions (Ref. 4). The technique may obviously be modified for those cases where another probability distribution is known to govern the parameters.

An exact analysis following the foregoing procedures would be very difficult and quite unnecessary because of the approximate nature of the distributions. Fortunately there exists a simplified method which gives approximately the same result. The required end-points are selected to produce at least 90 per cent probability of having no failures out of 11 tested parts (more precisely $(0.99)^{11} = 0.895$). The method assumes that the critical post-irradiation parameters approximately follow either a normal or, more likely, a log normal probability distribution. The end-points are then computed by determining a best estimate of the limit where 99 per cent of the parts for each of N lots

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will pass the test. If x is the critical parameter of interest, the best estimate for the end-point limit which includes 99 per cent of the distribution is:

$$x_{Li} = x_i +/- 2.326 \ s_i \qquad (1)$$

for parameters which increase or decrease respectively with radiation, where $x_{Li}$ is the end-point limit for the ith lot, $x_i$ is the mean value of $x$, and $s_i$ is the standard deviation. (The factor 2.326 arises from the fact that 2.326 standard deviations above the mean of a normal distribution includes 99 per cent of the distribution.) For the more usual cases where the post-irradiation parameter follows a log normal distribution, x would represent the logarithm of the parameter. A typical example of a parameter x would be the logarithm of the change in reciprocal gain, $\log[(1/h_{FE})]$.

If a sufficient number of parts are sampled from each lot, the values of the parameter of interest $X_L$ are approximately distributed according to a normal law. An example of such a distribution for seven lots of 2N2907s is shown in Figure 1. The end-point limit, $X_{LL}$, for the part type is then determined from the point where with 90 per cent confidence, at least a certain fraction, $P_a$, of future lots will have values of $X_L$ bounded by $X_{LL}$. The end-point, $X_{LL}$, is given by the approximation:

$$X_{LL} = X_L + k(N_L, \ P_a, \ C = 90\%)s_L \qquad (2)$$

where $N_L$ is the number of lots tested, $X_L$ is the mean for the $N_L$ lots, and $s_L$ is the standard deviation for the $N_L$ lots. The function k is the one-sided tolerance limit. Tables of values for k for various values of $N_L$ and $P_a$ are given by Namenson, et al. (Ref. 4). Values for k for low $P_a$ and small numbers of lots are shown in Table 2.

The validity of the approximation was checked by doing exact calculations on a typical set of data for 2N2222 transistors. The end-point obtained from the method given above was compared with an exact calculation and it was found that the actual confidence that 90 per cent of future lots would pass an 11/0 test was 86 per cent rather than 90 per cent which is sufficient accuracy for the purposes here. Similar checks on other data likewise show that the approximation is satisfactory.

The above calculations apply for estimating the post-neutron end-points from multilot data. A similar calculation applies for total dose end-points. The total dose RHA sampling requirement for class B or JANTXV devices is a 22/0 test. For a part survivability of 0.99, the multi-lot statistical limit requires a projection of only 80 per cent of the future lots passing, compared to 90 percent for a 11/0 test [i.e., $(0.99)^{22} = 0.80$].

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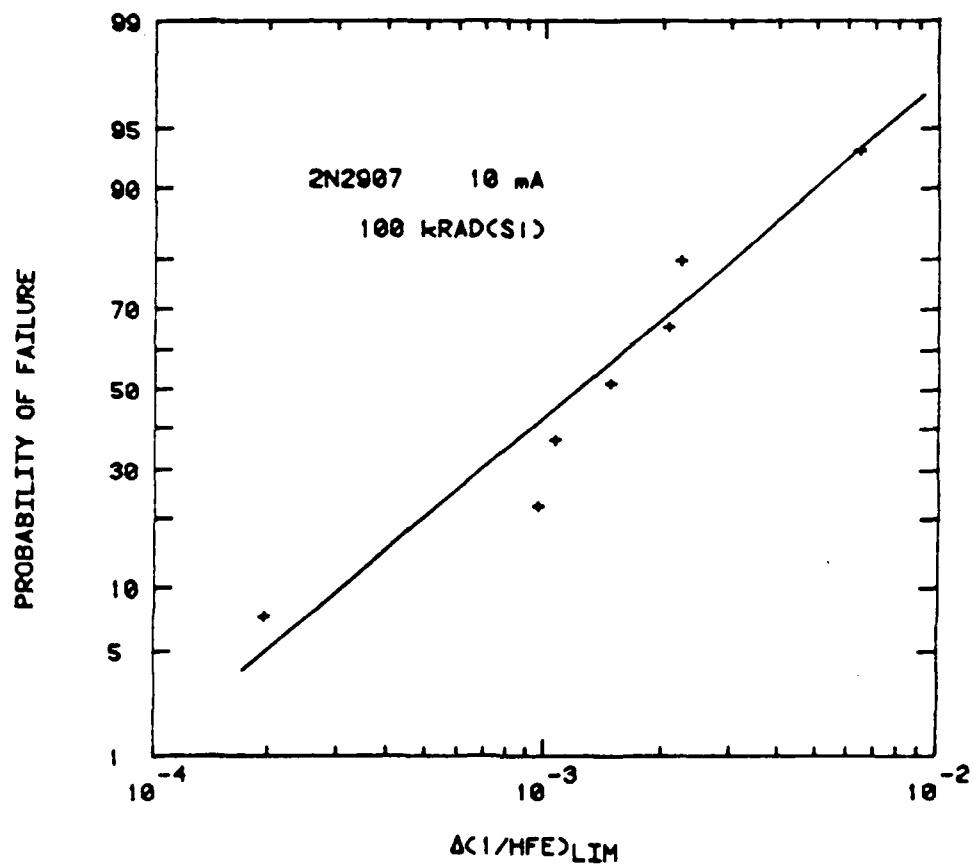
Figure 1.    Distribution of Lot Limit in $\Delta(1/h_{FE})$ at 100 krad(Si) for Seven Lots of 2N2907A.

Table 2. One-sided Tolerance Factors for Small No. Lots

| P (C = .9) | N | K | P | K (N = 5) |
|---|---|---|---|---|
| 50% | 2 | 2.18 | .95 | 3.40 |
|  | 3 | 1.09 | .90 | 2.74 |
|  | 4 | 0.82 | .8 | 1.98 |
|  | 5 | 0.68 | .75 | 1.70 |
|  | 6 | 0.602 | .6 | 1.041 |
|  | 7 | 0.54 | .5 | .68 |
|  |  |  | .4 | .362 |
| 75% | 3 | 2.602 |  |  |
|  | 4 | 1.972 |  |  |
|  | 5 | 1.70 |  |  |
|  | 6 | 1.54 |  |  |
|  | 7 | 1.435 |  |  |
| 90% | 3 | 4.26 |  |  |
|  | 4 | 3.2 |  |  |
|  | 5 | 2.74 |  |  |
|  | 6 | 2.49 |  |  |
|  | 7 | 2.33 |  |  |

## 2.2.2 Combined Environments Limits

The RHA tests defined in the group E/D RHA test tables specify separate tests for neutrons and total dose. The part designator (M, D, R, and H) implies that the part meets both neutron and total dose requirements and can be used in combined neutron and total dose environments. The part user must then find a means to either combine the individual end-point limits for each environment in a statistically valid manner or obtain characterization data (i.e., radiation test) to determine the part's performance in its intended application. Additional testing beyond QCI requirements undermines the purpose of RHA standardization and thus some means of applying attributes tests (go/no go) and specification end-points to combined environments are required.

Specific methods for calculating the combined effects of neutrons and total dose have been recommended ( e.g., Refs. 1-3). The approach utilized in this effort is to apply a "worst case" delta for neutron effects to the post-irradiation end-point limits for total dose. This adds some conservatism to the combined effects but yields the most consistent values.

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## 2.2.3 Example Calculations of End-Points

A comparison of the calculated multi-lot end-point limits with the individual lot limits is shown in Figure 2 for four lots of 2N2222A at $2 \times 10^{12}$ n/cm$^2$. The estimated pass/fail limit for $h_{FE}$ is calculated for each lot using Eq. (1). This lower limit is shown by the "x" at the lower end of the vertical bar for each lot in the figure. The number of devices in the lot test sample does not enter into this limit provided it is five or more. Assuming the lot limit distribution is approximately normal, the multi-lot lower limit can be computed using Eq. (2) for various lot acceptance probabilities. In this case, the 50 percent and 75 percent lot acceptance probabilities (at 90 percent confidence) are calculated and shown by the dashed lines in Figure 2.

These calculated multi-lot limits can be adjusted to some degree for end-points according to the "best estimate" of RHA yield and post-irradiation degradation to which the part might be used. For example, if a 50 percent gain degradation is acceptable for most applications (as is frequently the case in design derating practices for hardened designs), then the end-points corresponding to the higher acceptance probability could be accepted; the suppliers would have a higher acceptance rate and thus minimize cost impacts.

## 2.3 DATA STORAGE AND ANALYSIS

The data storage and analysis task for developing the end-point limits and post-irradiation characteristics for the six device types in this effort was primarily performed on a personal computer. Previously, a large computer program running on a VAX was used for crunching the huge volume of data for hundreds of part types. However the cost and manpower involved in the use of this program (Ref. 3) became prohibitive and the decision was made to use small computers for this effort.

## 2.4 RHA DEVELOPMENT FOR MIL-M-38510/101

MIL-M-38510/101F is the detail specification for eight types of monolithic silicon linear operational amplifiers. Significant radiation data are currently available for only the three most commonly used of these part types: the LM101A (-03), 741 (-01), and LM108A (-04). Most of the data available for these calculations were taken for specific equipment applications. Thus we were faced with the problem that the only set of device parameters common to all the lots were the input parameters, $V_{IO}$, $I_{IO}$, and $I_{IB}$. While these parameters were indeed the most critical to post-irradiation device operation, parameters such as open-loop gain, $A_{VS}$, and output sink
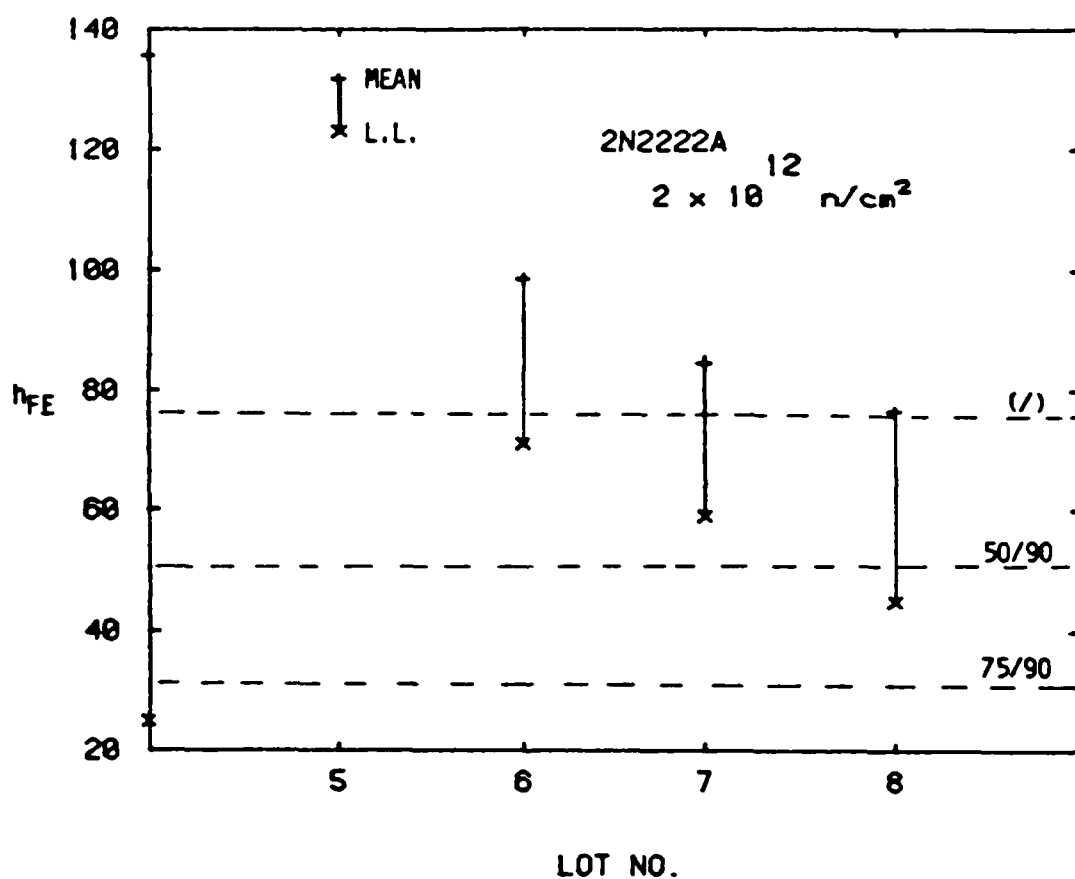
Figure 2. Lot Mean and Lower Limit (L.L.) and Multi-Lot Limit for $h_{FE2}$ at 1 mA and a Fluence of $2 \times 10^{12}$ n/cm$^2$ for 2N2222A.

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current, $I_{OS}$, can also be sensitive to radiation, but were only reported for some of the lots. This problem is to be expected because uniform standards and specifications for RHA characterization tests are not available or used.

Even though not all the necessary test parameters were The volume of radiation characterization data is much too large to include in detail in this report. A summary of some of the most important radiation characterization data and calculations/estimates of end-point limits and post-irradiation characteristics for each of the three op amps are included in the following sections.

2.4.1    Summary of LM741 Radiation Characterization Data

The LM741 is a general purpose op amp with NPN input transistors and lateral PNP current "mirrors". A substantial amount of data has been reported ( see, e.g., Ref. 4 ). However, radiation characterization data for only a few lots have been reported and stored in databanks in recent years. The two major sources of radiation characterization data for these device types are the Boeing CHAP databank and data stored on the Tektronix S-3260 IC tester. A summary of the multi-lot data extracted from these databanks for neutron and total dose degradation is shown in Table 3. The major parameters in their order of sensitivity are: input bias current ($I_{IB}$), input offset current ($I_{IO}$), input offset voltage ($V_{IO}$), open-loop gain ($A_{VS}$), and output sink current ($I_{OS}$). The last column of this table includes the calculated or estimated post-irradiation end-point.

The following approach was used to determine these values:

1)    Limits were computed for both + and - inputs for the input bias current. The limit selected was the larger.

2)    Limits for offset voltage --- compute upper and lower limits, take larger and either sign.

3)    Limits of offset current --- same approach as 2).

4)    Limits for open loop gain --- select single load and compute limits similar to $h_{FE}$.

5)    Limits for sink current --- compute limits similar to $h_{FE}$ (constant base current).

2.4.2    Summary of LM101A Radiation Characterization Data

The LM101A is a general purpose operational amplifier with low input currents and temperature drifts. A large amount of radiation characterization data has been collected for the

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Table 3.   MULTILOT RADIATION END-POINT LIMIT DATA SUMMARY LM741.

| | | | | | | 1 | 2 | 3 | 4 | |
| | | | | | | LOT LIMIT | LOT LIMIT | LOT LIMIT | LOT LIMIT | |
| DEVICE TYPE | SLASH NO. | PARAM. | BIAS | PRE-RAD. END-POINT | STRESS | INTER. 8428 | NAT 8234 | NAT 8337 | FSC 8010 | END-POINT LIMIT |
|---|---|---|---|---|---|---|---|---|---|---|
| LM741 | 10101 | VIO | | +/- 3 mV | 2.0E12 | | | | | 5.0 mV |
| | | | | | 3000 | | | 1.6 | | 5.0 |
| | | | | | 1.0E4 | | 0.0 | 1.7 | | 5.0 |
| | | | | | 1.0E5 | | 13.0 | 2.5 | | 20 |
| | | | | | 1.0E6 | | 600.0 | | | 100 |
| | | IIO | | +/- 30 nA | 2.0E12 | | | | | 50 nA |
| | | | | | 3000 | | | 2.2 | | 50 |
| | | | | | 1.0E4 | | | 3.0 | | 50 |
| | | | | | 1.0E5 | | 27.0 | 5.0 | | 50 |
| | | | | | 1.0E6 | | | | | 100 |
| | | IIB | | 110 nA | 2.0E12 | DL=360 | | DL=232 | | 500 nA |
| | | | | | 3000 | | 150.0 | 60.0 | | 200 |
| | | | | | 1.0E4 | | 170.0 | 80.0 | | 300 |
| | | | | | 1.0E5 | | 313.0 | 137.0 | | 500 |
| | | | | | 1.0E6 | | 1414.0 | | | 1000 |
| | | AVS | RL = 2K VO = 15V | 50 K | 2.0E12 | | | | | (45K) |
| | | | | | 3000 | | | | | (45K) |
| | | | | | 1.0E4 | | | | | (45K) |
| | | | | | 1.0E5 | | | | | (45K) |
| | | | | | 1.0E6 | | | | | (45K) |
| | | IOS | | 60 mA | 2.0E12 | | | | | (55 mA) |
| | | | | | 3000 | | | | | (55) |
| | | | | | 1.0E4 | | | | | (55) |
| | | | | | 1.0E5 | | | | | (55) |
| | | | | | 1.0E6 | | | | | (55) |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |

LM101A.    Table 4 includes a listing for the 11 lots   analyzed.
Most   of these   were taken for specific applications    and   only
the input parameters are common to these data.   Total dose data
on open loop gain was included in only two lots analyzed.    The
lot   failure   limit   data   for   these   two   lots   are   shown   in
Figure 4.    In general, $A_{VS}$ degradation was not significant un-
til   moderately   high doses (above R   level),   whereupon   large
changes occurred.   On the other hand, input bias currents, $I_{IB}$,
and offset currents,   $I_{IO}$, degraded at much lower doses and ex-
hibited large lot-to-lot variations.    This is shown in Figures
5 and 6 for three lots.   Figure 5 shows the upper limit for in-
put offset current degradation.   The data for one lot exhibited
large variations which is likely due to test errors.   The input
bias   current,   which displays the most consistent   degradation
behavior   with   total   dose (Figure 6),   also   exhibited   large
variations between lots.    The calculated end-points are   shown
in the last column on page 3 of Table 4.

2.4.3      Summary of LM108A Radiation Characterization Data

     The LM108A is a precision operational amplifier which uti-
lizes super-gain NPN transistors in the input stage to   achieve
very low input parameter values ($V_{IO}$ max of 0.5 mV,   $I_{IO}$ max of
0.2 nA,   $I_{IB}$ max of 2.0 nA).    These high precision performance
requirements make the LM108A very sensitive to radiation damage
and the typical post-irradiation parameter values exceed   these
specification limits at low radiation values.    This is   illus-
trated in Table 5 which is a matrix of lot failure for   several
parameters and radiation levels.   Table 5 shows the number   of
devices   from   each   lot   whose   parameter   values   exceed   the
pre-irradiation   limits.    As   expected,   the   input   parameters
dominate   the failure mode for nearly all lots,   both for   neu-
trons   and total dose.    The results of   multi-lot   statistical
analysis demonstrate that a substantial derating of   electrical
end-points is required in order that these device pass   RHA re-
quirements.   This is balanced against the "over-derating" which
obviates   the performance advantage of the higher initial   per-
formance (and initial cost) of this device.

     Table 6 is a summary of the lots for which radiation   data
were analyzed.   The data for many of the LM108A lots,   for which
data were identified (some shown on Table   ),   were not   avail-
able   for this RHA analysis due to problems with   the   computer
data   files.    Many of the neutron data files had been   removed
and   due to change-over in databases.    For example,   only   two
lots   of these devices were available for neutron RHA   calcula-
tions   out   of over 15 lots identified.    The majority of   the
"lost" lots were unavailable due to their removal from computer
databases.    However,   more   than   ten   lots   of   LM108As   were
analyzed   earlier   for lot failures based on the use   of   their
preirradiation end-point limits.    These data,   though unavail-
able for multi-lot analyses,   could be used to estimate failure
parameter values.

Table 4. MULTILOT RADIATION END-POINT LIMIT DATA SUMMARY FOR LM101A

| DEVICE TYPE | SLASH NO. | PARAM. | BIAS | PRE-RAD. END-POINT | STRESS | 1 LOT LIMIT FSC FJ82 | 2 LOT LIMIT FSC 8346 | 3 LOT LIMIT SIG 7931 | 4 LOT LIMIT AMD 8115 | END-POINT LIMIT |
|---|---|---|---|---|---|---|---|---|---|---|
| LM101A | 101 | -VIO | | -2.0 mV | 2.0E12 | -2.0 | -2.1 | -1.5 | -1.2 | (CONT.) |
| | | | | | 3000 | | -2.0 | | | |
| | | | | | 1.0E4 | | -2.4 | | | |
| | | | | | 1.0E5 | | -4.1 | | | |
| | | | | | 1.0E6 | | -6.7 | | | |
| | | +VIO | | +2.0 mV | 2.0E12 | 1.3 | 1.4 | 2.3 | 2.1 | |
| | | | | | 3000 | | 2.6 | | | |
| | | | | | 1.0E4 | | 1.8 | | | |
| | | | | | 1.0E5 | | 1.2 | | | |
| | | | | | 1.0E6 | | 1.5 | | | |
| | | IIO | | 10 nA | 2.0E12 | 5.3 | 14.0 | 11.3 | 5.7 | |
| | | | | | 3000 | | 6.0 | | | |
| | | | | | 1.0E4 | | 4.6 | | | |
| | | | | | 1.0E5 | | 19.0 | | | |
| | | | | | 1.0E6 | | 34.0 | | | |
| | | IIB | | 75 nA | 2.0E12 | 46.0 | 52.0 | 85.0 | 87.0 | |
| | | | | | 3000 | | 20.0 | | | |
| | | | | | 1.0E4 | | 84.0 | | | |
| | | | | | 1.0E5 | | 254.0 | | | |
| | | | | | 1.0E6 | | 427.0 | | | |
| | | AVS | RL = 2K VO = 15V | 50 K | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |
| | | IOS | | 60 mA | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |

Table 4.    MULTILOT RADIATION END-POINT LIMIT DATA SUMMARY FOR LM101A (cont.)

| | | | | | | 5 | 6 | 7 | 8 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LOT LIMIT | LOT LIMIT | LOT LIMIT | LOT LIMIT | |
| DEVICE TYPE | SLASH NO. | PARAM. | BIAS | PRE-RAD. END-POINT | STRESS | FSC 8424 | NAT 0857 | NAT 0858 | NAT 0859 | END-POINT LIMIT |
| LM101A | 101 | -VIO | | -2.0 mV | 2.0E12 | -1.4 | | | | (CONT.) |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | -1.4 | -0.3 | -0.7 | -1.3 | |
| | | | | | 1.0E5 | -2.2 | -0.8 | -1.7 | -2.3 | |
| | | | | | 1.0E6 | | -6.5 | -18.5 | -4.9 | |
| | | +VIO | | +2.0 mV | 2.0E12 | 0.1 | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | -0.2 | 0.5 | 0.7 | 2.0 | |
| | | | | | 1.0E5 | -0.1 | 0.0 | 0.9 | 2.9 | |
| | | | | | 1.0E6 | | 3.3 | 2.8 | 0.0 | |
| | | IIO | | 10 nA | 2.0E12 | 5.5 | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | 1.3 | 3.3 | 2.2 | 2.8 | |
| | | | | | 1.0E5 | 4.5 | 42.0 | 10.0 | -7.0 | |
| | | | | | 1.0E6 | | 43.4 | 50.0 | -63.0 | |
| | | IIB | | 75 nA | 2.0E12 | 57.0 | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | 48.0 | 57.0 | 58.0 | 52.0 | |
| | | | | | 1.0E5 | 116.0 | 210.0 | 144.0 | 81.0 | |
| | | | | | 1.0E6 | | 583.0 | 375.0 | 236.0 | |
| | | AVS | RL = 2K VO = 15v | 50 K | 2.0E12 | 1.33E+05 | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | 1.04E+05 | 2.70E+05 | 1.60E+05 | 1.80E+05 | |
| | | | | | 1.0E5 | 1.50E+04 | | 1.80E+05 | 1.92E+05 | |
| | | | | | 1.0E6 | | | 2.00E+03 | 1.00E+03 | |
| | | IOS | | 60 mA | 2.0E12 | 28.0 | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | 29.0 | | | | |
| | | | | | 1.0E5 | 17.0 | | | | |
| | | | | | 1.0E6 | | | | | |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |

Table 4.　　MULTILOT RADIATION END-POINT LIMIT DATA SUMMARY FOR LM101A (cont.)

| DEVICE TYPE | SLASH NO. | PARAM. | BIAS | PRE-RAD. END-POINT | STRESS | 9 LOT LIMIT FSC 8346 | 10 LOT LIMIT FSC FJ82 | 11 LOT LIMIT FSC 8011 | 12 LOT LIMIT | END-POINT LIMIT |
|---|---|---|---|---|---|---|---|---|---|---|
| LM101A | 101 | -VIO | | -2.0 mV | 2.0E12 | | | | | 5 mV |
| | | | | | 3000 | -2.0 | -1.9 | 3.0 | | 10 |
| | | | | | 1.0E4 | -2.0 | -2.1 | 1.0 | | 10 |
| | | | | | 1.0E5 | -2.1 | -2.5 | -1.3 | | 15 |
| | | | | | 1.0E6 | -2.2 | -3.1 | -8.2 | | 25 |
| | | +VIO | | +2.0 mV | 2.0E12 | | | | | 5 mV |
| | | | | | 3000 | 1.3 | 1.5 | 9.6 | | 10 |
| | | | | | 1.0E4 | 1.0 | 1.3 | 5.9 | | 10 |
| | | | | | 1.0E5 | ⁻.3 | 0.9 | 0.1 | | 15 |
| | | | | | 1.0E6 | -0.3 | 0.7 | -5.1 | | 25 |
| | | IIO | | 10 nA | 2.0E12 | | | | | 20 nA |
| | | | | | 3000 | | 57.0 | | | 20 |
| | | | | | 1.0E4 | | 14.0 | | | 20 |
| | | | | | 1.0E5 | | 147.0 | | | 175 |
| | | | | | 1.0E6 | | 280.0 | | | 380 |
| | | IIB | | 75 nA | 2.0E12 | | | | | 120 nA |
| | | | | | 3000 | 45.0 | 60.0 | | | 100 |
| | | | | | 1.0E4 | 71.0 | 66.0 | | | 100 |
| | | | | | 1.0E5 | 123.0 | 228.0 | | | 320 |
| | | | | | 1.0E6 | 179.0 | 393.0 | | | 760 |
| | | AVS | RL = 2K VO = 15V | 50 K | 2.0E12 | | | | | 45 K |
| | | | | | 3000 | | | | | 45 |
| | | | | | 1.0E4 | | | | | 45 |
| | | | | | 1.0E5 | | | | | 5 |
| | | | | | 1.0E6 | | | | | --- |
| | | IOS | | 60 mA | 2.0E12 | | | | | (55 mA) |
| | | | | | 3000 | | | | | (55 mA) |
| | | | | | 1.0E4 | | | | | (55 mA) |
| | | | | | 1.0E5 | | | | | (55 mA) |
| | | | | | 1.0E6 | | | | | (55 mA) |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |

Figure 3. Lot Limit for Open-Loop Gain, $A_{vs}$, versus Total Dose for Two Lots of LM101A.
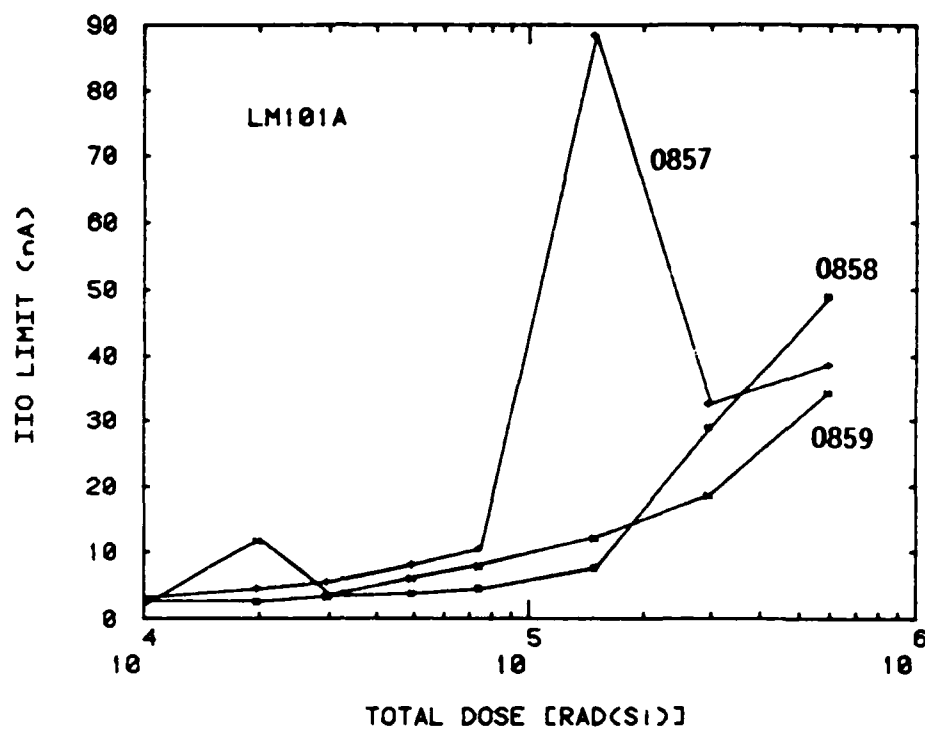
Figure 4. Lot Limit for Input Offset Current, $I_{IO}$, versus Total Dose for Three Lots of LM101A.
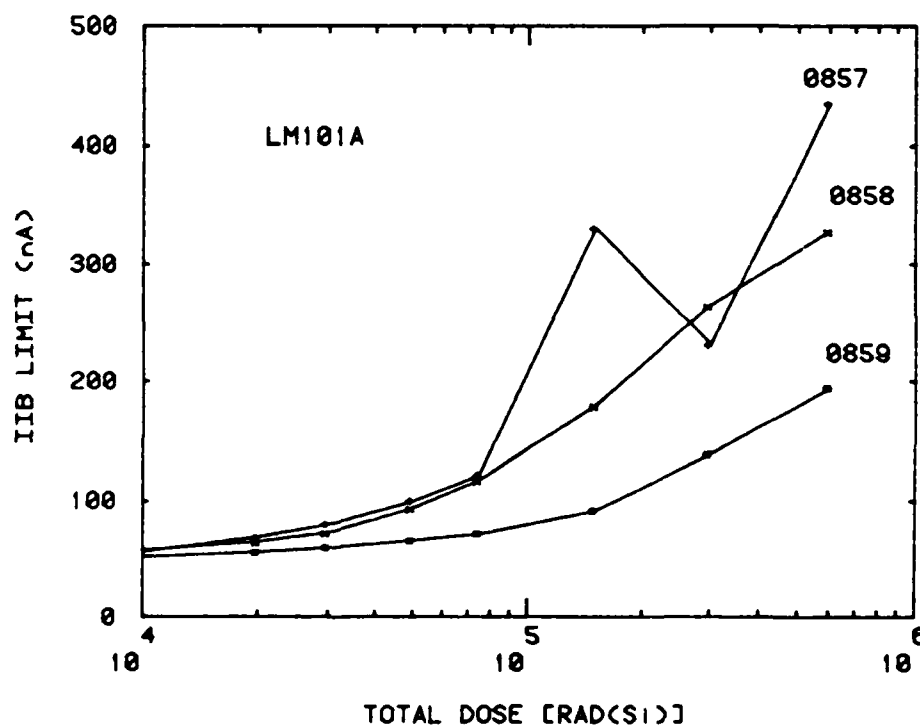


Figure 5. Lot Limit for Input Bias Current, $I_{IB}$, versus Total Dose for Three Lots of LM101A.

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## Table 5. EXAMPLE OF LOT SAMPLE FAILURE MATRIX - LM 108A

| PART TYPE | MFR | DATE CODE | LOT SIZE | RADIATION LEVEL | N/D | IIB $+2$ $-.1$ nA | VIO $\pm.5$mV | IIO $\pm.2$nA | AVS 80K | SR | IOS $\pm15$mA | ICC 600µA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LM108A | FSC | 7720 | 15 | $5.5\times10^{11}$ | n/cm$^2$ | 15 | 1 | 8 | 0 | | 0 | 0 |
| | | | | $1.1\times10^{12}$ | | 15 | 1 | 10 | 4 | | | 0 |
| | | | | $4.0\times10^{12}$ | | 15 | 9 | 13 | 15 | | | 0 |
| | | | | $6.1\times10^{12}$ | | 15 | 15 | 15 | 15 | | | 0 |
| LM108A | NSC | 7642 | 15 | $1.6\times10^{12}$ | n/cm$^2$ | 15 | 2 | 10 | 2 | | 0 | 0 |
| | | | | $3.1\times10^{12}$ | | 15 | 4 | 8 | 12 | | 0 | 0 |
| | | | | $8.1\times10^{12}$ | | 15 | 15 | 15 | 15 | | 0 | 0 |
| LM108A | AMD | 7721 | 8 | $1.1\times10^{12}$ | n/cm$^2$ | 8 | 4 | 4 | 8 | | 0 | 0 |
| | | | | $3.1\times10^{12}$ | | 8 | 8 | 7 | 8 | | 0 | 0 |
| | | | | $8.4\times10^{12}$ | | 8 | 8 | 8 | 8 | | Q | 0 |
| LM108A | AMD | 8215 | 5 | $1\times10^{4}$ | rad(Si) | 0 | 0 | 0 | 0 | | | 0 |
| | | | | $2\times10^{4}$ | | 0 | 0 | 0 | 0 | | | 0 |
| | | | | $1\times10^{5}$ | | 1 | 1 | 0 | 0 | | | 0 |
| | | | | $3\times10^{5}$ | | 1 | 1 | 0 | 0 | | | 0 |
| | | | | $1\times10^{6}$ | | 5 | 2 | 0 | 0 | | | 0 |
| | | | | $3\times10^{6}$ | | 5 | 5 | 3 | 2 | | | |
| LM108A | FSC | 8348 | 5 | $1\times10^{4}$ | rad(Si) | | 0 | | 0 | | | 0 |
| | | | | $5\times10^{4}$ | | | 2 | | 0 | | | 0 |
| | | | | $1\times10^{5}$ | | | 5 | | 5 | | | 0 |
| | | | | $5\times10^{5}$ | | | 5 | | 5 | | | 0 |
| | | | | $1\times10^{6}$ | | | 5 | | 5 | | | 0 |

Table 6. Summary of LM108A Lots Used for RHA Devices

| LOT | MFR | DATE | No | SRCE | PARM | DOSE | FLUENCE |
|-----|-----|------|-----|------|------|------|---------|
| 1 | AMD | 8215D | 10 | BA | 3/5 | 10-300K | $.5-7 \times 10^{12}$ |
| 2 | AMD | 8049 | 10 | BA | 3/5 | 5-200K | $7 \times 10^{10}$ |
| 3 | AMD | 8049A | 5 | BA | 3/5 | | |
| 4 | NAT | -- | 3/6 | BA | 5/5 | 10-300K | ---- |
| 5 | AMD | 8238/ | 5 | JPL | 4/5 | 75-1000K | ---- |
| 6 | PMI | E9974 | 5 | JPL | 4/ | 75-1000K | ---- |
| 7 | MOT | 8143 | 5 | JPL | 4/ | 10-50K | ---- |
| 8 | NAT | 0855-1 | 5 | JPL | 4/ | 10-600K | ---- |
| 9 | FSC | 8223 | 4 | JPL | 4/ | 10-600K | ---- |
| 10 | AMD | 8238-39 | 5 | JPL | 4/ | 75-1000K | ---- |

A sample calculation of the D- and R- level end-points for Subgroup 2, Total Dose, is shown in Table 7 for input bias current for the six devices (lot 4 in Table 6). The device serial number is shown in the first column with the input bias current in nA shown in each column after exposure to the total dose level in rad(Si) shown in the column heading. The log mean and standard deviation and lot limit, XL, are listed beneath the measured data. No end-point could be calculated for the H-level (1 Mrad) due to constraints on extrapolating data more than a factor of two.

Table 7. Example of Lot Limit Estimate for IIB for LM108A

| S/N | PRE | 10K | 30K | 60K | 100K | 200K | 300K | 1M |
|-----|-----|-----|-----|-----|------|------|------|-----|
| 31 | 1.04 | 1.27 | 1.49 | 1.80 | 2.30 | 3.10 | 3.80 | (*) |
| 32 | 0.86 | 1.15 | 1.43 | 1.80 | 2.20 | 3.10 | 3.85 | |
| 33 | 1.29 | 1.29 | 1.80 | 2.20 | 2.70 | 3.60 | 4.30 | |
| | | | | | | | | |
| 21 | 1.12 | 1.19 | 12.70 | 12.70 | 4.70 | | | |
| 22 | 0.50 | 0.54 | 0.84 | 0.85 | 1.40 | | | |
| 23 | 1.06 | 1.18 | 2.40 | 2.40 | 2.90 | | | |
| | | | | | | | | |
| L-MEAN | 1.09 | | | | 2.53 | | | --- |
| L-SIG | 0.15 | | | | 0.17 | | | --- |
| | | | | | | | | |
| XL | 2.48 nA | | | | 6.35 nA | | | --- |

Table 8 is a summary of the individual lot limits for the ten lots of LM108A. The last two columns (page 3 of Table 8) are the multi-lot limits and recommended end-points values.

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Table 8. MULTILOT RADIATION END-POINT LIMIT DATA SUMMARY FOR LM108A

| | | | | | | 1 LOT LIMIT | 2 LOT LIMIT | 3 LOT LIMIT | 4 LOT LIMIT | |
| | | | | | | AMD | AMD | AMD | NAT | END-POINT |
| DEVICE TYPE | SLASH NO. | PARAM. | BIAS | PRE-RAD. END-POINT | STRESS | 8215 | 8049 | 8049 | | LIMIT |
|---|---|---|---|---|---|---|---|---|---|---|
| LM108A | 101 | VIO | | 0.5 mV | 2.0E12 | 1.50 | | | | (CONT.) |
| | | | | | 3000 | | 4.0 | 0.14 | 0.66 | |
| | | | | | 1.0E4 | | 4.8 | 0.44 | 1.10 | |
| | | | | | 1.0E5 | 2.00 | 6.5 | 2.10 | 1.30 | |
| | | | | | 1.0E6 | 3.00 | 8.2 | 3.90 | 0.02 | |
| | | IIO | | 0.2 nA | 2.0E12 | 0.60 | | | | |
| | | | | | 3000 | | 0.8 | 0.80 | 0.20 | |
| | | | | | 1.0E4 | | 0.8 | 0.60 | 0.07 | |
| | | | | | 1.0E5 | 0.02 | 1.3 | 1.00 | 0.13 | |
| | | | | | 1.0E6 | 0.50 | 1.7 | 1.70 | 0.02 | |
| | | IIB | | 2.0 nA | 2.0E12 | 3.97 | | | | |
| | | | | | 3000 | | 23.1 | 5.8 | 3.30 | |
| | | | | | 1.0E4 | | 28.0 | 2.0 | | |
| | | | | | 1.0E5 | 3.0 | 40.0 | 20.0 | | |
| | | | | | 1.0E6 | 15.0 | 53.0 | 39.0 | | |
| | | AVS | | 80 K | 2.0E12 | 2.2E+04 | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |
| | | IOS | | 15 mA | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |

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| | | | | | | 5 | 6 | 7 | 8 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LOT LIMIT | LOT LIMIT | LOT LIMIT | LOT LIMIT | |
| DEVICE TYPE | SLASH NO. | PARAM. | BIAS | PRE-RAD. END-POINT | STRESS | AMD | PMI | MOT | NAT | END-POINT |
| | | | | | | 8238 | E9974 | 8143 | 0855-1 | LIMIT |
| LM108A | 101 | VIO | | 0.5 mV | 2.0E12 | | | | | (CONT.) |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | 4.80 | 3.4 | |
| | | | | | 1.0E5 | 4.2 | 0.9 | | 24.0 | |
| | | | | | 1.0E6 | 2.1 | 1.0 | | | |
| | | IIO | | 0.2 nA | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | 0.7 | |
| | | | | | 1.0E5 | 4.2 | | | 8.0 | |
| | | | | | 1.0E6 | 10.2 | | | | |
| | | IIB | | 2.0 nA | 2.0E12 | 3.9 | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | 3.9 | 3.8 | |
| | | | | | 1.0E5 | 58.2 | 13.0 | | 4.3 | |
| | | | | | 1.0E6 | 95 | 25.0 | | | |
| | | AVS | | 80 K | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | 3.4E+04 | 2.4E+04 | |
| | | | | | 1.0E5 | | 1.8E+04 | --- | 2.4E+02 | |
| | | | | | 1.0E6 | | | | | |
| | | IOS | | 15 mA | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |

| | | | | | | 9 | 10 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LOT LIMIT | LOT LIMIT | LOT LIMIT | LOT LIMIT | |
| DEVICE TYPE | SLASH NO. | PARAM. | BIAS | PRE-RAD. END-POINT | STRESS | FSC 8223 | AMD 8238 | | MULTI-LOT LIMIT | END-POINT LIMIT |
| LM108A | 101 | VIO | | 0.5 mV | 2.0E12 | | | | (1.5) | 3 mV |
| | | | | | 3000 | | | | 10.5 | 10 |
| | | | | | 1.0E4 | 1.20 | | | 7.5 | 10 |
| | | | | | 1.0E5 | 31.0 | 0.4 | | 33(7.5) | 10 |
| | | | | | 1.0E6 | | 0.7 | | 9.2 | 10 |
| | | IIO | | 0.2 nA | 2.0E12 | | | | (0.6) | 2 nA |
| | | | | | 3000 | | | | 2.1 | 2 |
| | | | | | 1.0E4 | 15.70 | | | 29.5(1.3) | 2 |
| | | | | | 1.0E5 | 27.0 | 1.4 | | 24(8.4) | 8 |
| | | | | | 1.0E6 | | 9.1 | | 13.4 | 13 |
| | | IIB | | 2.0 nA | 2.0E12 | | | | (4.4) | 10 nA |
| | | | | | 3000 | | | | (3.6) | 20 |
| | | | | | 1.0E4 | 25.90 | | | 114.0 | 100 |
| | | | | | 1.0E5 | 92.0 | 21.7 | | 191.0 | 200 |
| | | | | | 1.0E6 | | 80.0 | | 245.0 | 250 |
| | | AVS | | 80 K | 2.0E12 | | | | 2.2E+04 | 10K |
| | | | | | 3000 | | | | | 20K |
| | | | | | 1.0E4 | 2.4E+04 | | | 1.2E+04 | 12K |
| | | | | | 1.0E5 | | 6.7E+04 | | --- | 5K |
| | | | | | 1.0E6 | | | | | |
| | | IOS | | 15 mA | 2.0E12 | | | | 12 | 12 mA |
| | | | | | 3000 | | | | | 12 |
| | | | | | 1.0E4 | | | | | 12 |
| | | | | | 1.0E5 | | | | | 12 |
| | | | | | 1.0E6 | | | | | 12 |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |

## 2.5    RHA DEVELOPMENT FOR MIL-S-19500/323    (2N3251A)

The 2N3251A is a low power, PNP silicon switching transistor. Radiation characterization data for five lots were analyzed and lot parameter limits are summarized in Table 9. Of the four original lots with post-neutron $V_{CE(SAT)}$ data, only one lot had conditions consistent with the multi-lot analysis. For those cases where data on only one or two lots were available, limit values for delta changes were used to determine the post-irradiation end-point limits.

## 2.6    RHA DEVELOPMENT FOR S-3295/350    (2N3868)

The 2N3868 is a PNP silicon transistor rated at 3 A and 60 V with an $f_T$ of 60 MHz. Radiation characterization data on 25 parts of one lot (Motorola, D/C 8109) and five parts of a second lot (T.I., D/C 8408) have been analyzed and summarized below. Both lots exhibited large variation in parameter values. The use of absolute parameter statistical limits can result in extremely low (or high depending upon parameter) values for the estimated lot failure limits for non-uniform lots. For these cases, a more realistic failure limit is obtained using limiting values for parameter deltas and applying these delta limits to the pre-irradiation end-point limits. This is the approach used for determining post-irradiation end-points for these devices.

The large variability in initial parameter values and small variability in parameter degradation is demonstrated in the data plotted in Figures 6 and 7 where the range, mean, and standard deviation in parameter values for one lot is shown as a function of total dose. The variations within a single lot sample of five devices were substantially greater than the total dose degradation. The log normal lower limit computed for this lot is unrealistically low at all dose levels and simple statistical methods give unrealistically low values. The summary of end-points calculated using delta limits is shown in Table 10.

## 2.7    RHA DEVELOPMENT FOR MIL-S-19500/355    (2N2920)

The 2N2920 is a dual unitized NPN silicon transistor with matching $h_{FE}$ and $V_{BE}$ specifications for the transistor pair. Previous drafts of the RHA detail specification for this part lacked the gain matching specifications. Radiation characterization data taken at JPL on gain matching has been analyzed and included in the draft RHA amendment prepared in this effort. The multi-lot limits for $h_{FE}$ and gain ratio are shown in Figures 8, 9 and 10 as a function of total dose. The lower limit for $h_{FE}$ is shown for lot acceptance probabilities of 50%, 75%, and 90%. The large lot-to-lot variability at these

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Table 9  MULTILOT RADIATION END-POINT LIMIT DATA SUMMARY FOR 2N3251A

| | | | | | | 1 | 2 | 3 | 4 | |
| | | | | | | LOT LIMIT | LOT LIMIT | LOT LIMIT | LOT LIMIT | |
| DEVICE TYPE | SLASH NO. | PARAM. | BIAS | PRE-RAD. END-POINT | STRESS | MOT JPL 0245 | MOT 8044/ND16 | NAT ND3 | RAY ND6 | END-POINT LIMIT |
|---|---|---|---|---|---|---|---|---|---|---|
| 2N3251A | 323B | hFE | 0.1 mA | 80 | 2.0E12 | | 104 | 73 | 76 | 70 |
| | | | | | 3000 | | | | | 70 |
| | | | | | 1.0E4 | 163 | 108 | | | 70 |
| | | | | | 1.0E5 | 92 | 87 | | | 70 |
| | | | | | 1.0E6 | | 38 | | | 40 |
| | | hFE | 1 mA | 90 | 2.0E12 | | 148 | 115 | 127 | 80 |
| | | | | | 3000 | | | | | 80 |
| | | | | | 1.0E4 | 191 | 136 | | | 80 |
| | | | | | 1.0E5 | 134 | 119 | | | 80 |
| | | | | | 1.0E6 | | 72 | | | 60 |
| | | hFE | 10 mA | 100 | 2.0E12 | | 176 | 147 | 157 | 90 |
| | | | | | 3000 | | | | | 90 |
| | | | | | 1.0E4 | | 157 | | | 90 |
| | | | | | 1.0E5 | | 144 | | | 90 |
| | | | | | 1.0E6 | | 107 | | | 90 |
| | | hFE | 50 mA | 30 | 2.0E12 | | | 107 | 104 | 27 |
| | | | | | 3000 | | | | | 27 |
| | | | | | 1.0E4 | | 95 | | | 27 |
| | | | | | 1.0E5 | | 87 | | | 27 |
| | | | | | 1.0E6 | | 69 | | | 27 |
| | | VCE(SAT) | 10 mA/1mA | 0.25 | 2.0E12 | | 0.016 * | | | 0.30 |
| | | | | | 3000 | | | | | 0.30 |
| | | | | | 1.0E4 | | 0.08 | | | 0.30 |
| | | | | | 1.0E5 | | 0.09 | | | 0.30 |
| | | | | | 1.0E6 | | 0.10 | | | 0 30 |
| | | ICBO | 40 Vdc | 20 nA | 2.0E12 | | --- | | | 40 |
| | | | | | 3000 | | 1.6 | | | 40 |
| | | | | | 1.0E4 | | 3.0 | | | 40 |
| | | | | | 1.0E5 | | 7.0 | | | 50 |
| | | | | | 1.0E6 | | 82.0 | | | 100 |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | *DELTA LIM | | | |

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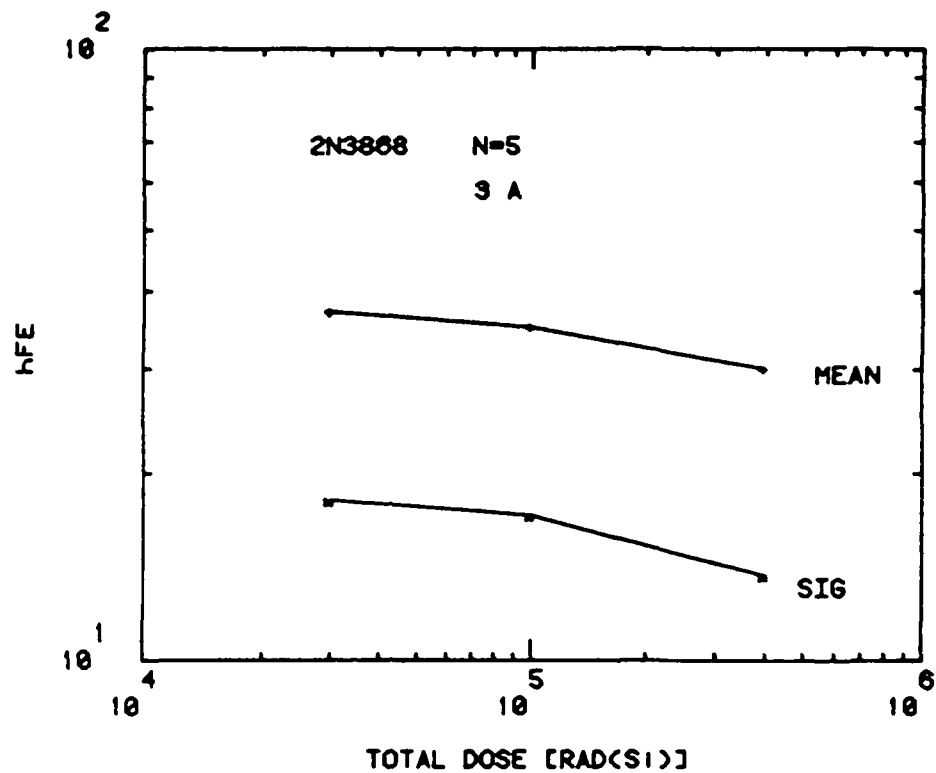
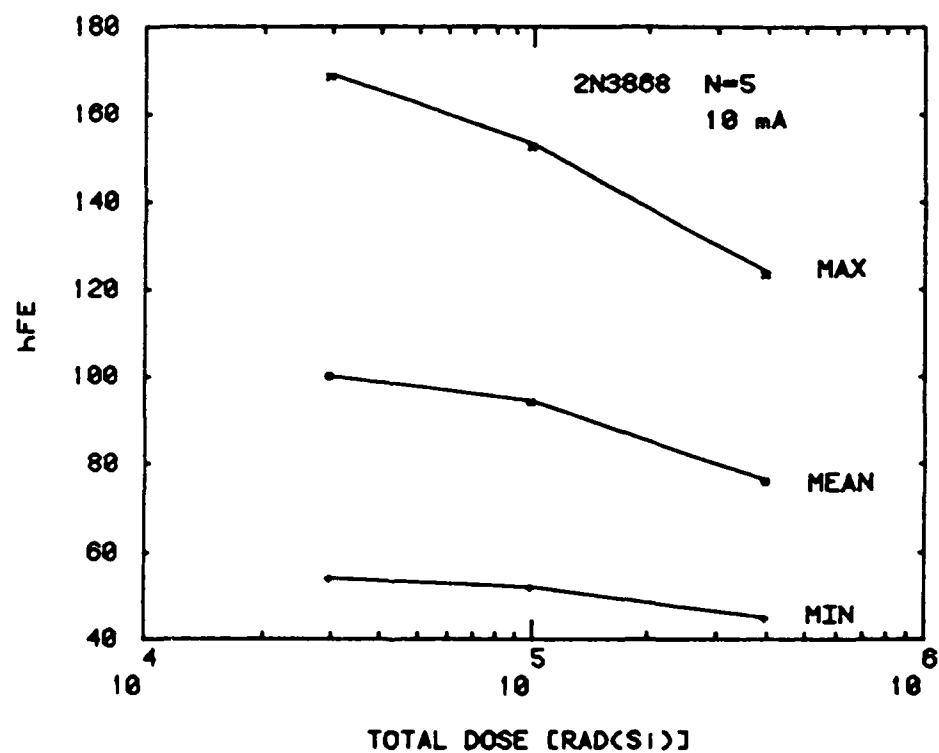Figure 6    Lot Mean and Standard Deviation versus Total Dose for
2N3868.



Figure 7    Lot Mean, Max, and Min versus Total Dose for One Lot
of 2N3868.

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Table 10.    MULTILOT RADIATION END-POINT LIMIT DATA SUMMARY FOR 2N3868

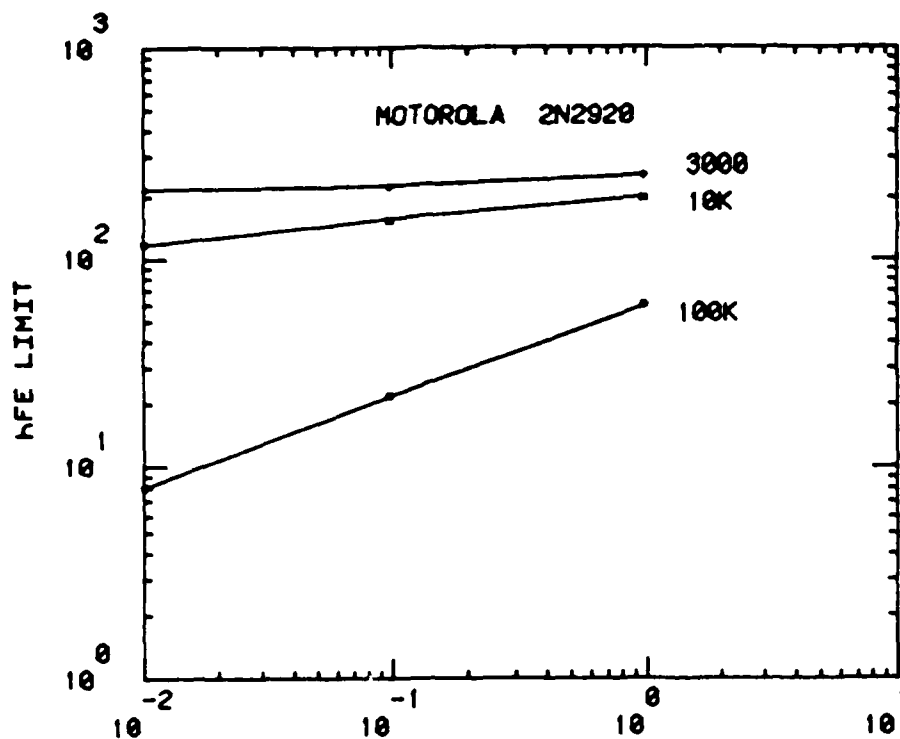| | | | | | | 1 | 2 | 3 | 4 | |
| | | | | | | LOT LIMIT | LOT LIMIT | LOT LIMIT | LOT LIMIT | |
| DEVICE TYPE | SLASH NO. | PARAM. | BIAS | PRE-RAD. END-POINT | STRESS | MOT 8109 N=25 | T.I. 8408 N=5 | | | END-POINT LIMIT |
|---|---|---|---|---|---|---|---|---|---|---|
| 2N3868 | 350A | hFE | 2V / 1.5A | 30.00 | 2.0E12 | 26 | | | | 20.00 |
| | | | | | 3000 | | | | | 27.00 |
| | | | | | 1.0E4 | | 29 | | | 27.00 |
| | | | | | 1.0E5 | | 28 | | | 22.00 |
| | | | | | 1.0E6 | | 21 | | | 10.00 |
| | | hFE | 5V / 3A | 20.00 | 2.0E12 | 19 | | | | 16.00 |
| | | | | | 3000 | | | | | 18.00 |
| | | | | | 1.0E4 | | 19 | | | 18.00 |
| | | | | | 1.0E5 | | 18 | | | 12.00 |
| | | | | | 1.0E6 | | 13 | | | 5.00 |
| | | VCE(SAT) | 1.5A/.15A | 0.75 Vdc | 2.0E12 | D=0.12 V | | | | 0.90 |
| | | | | | 3000 | | | | | 0.90 |
| | | | | | 1.0E4 | | | | | 0.90 |
| | | | | | 1.0E5 | | | | | 0.90 |
| | | | | | 1.0E6 | | | | | 1.00 |
| | | ICEX | VCB=60 V VEB=-2 V | -1.0 uA | 2.0E12 | 20 nA | | | | -1.2 uA |
| | | | | | 3000 | | | | | -1.2 uA |
| | | | | | 1.0E4 | | | | | -1.2 uA |
| | | | | | 1.0E5 | | 120 nA | | | -1.2 uA |
| | | | | | 1.0E6 | | 120 nA | | | -2.0 uA |
| | | D(1/hFE) | 1.5 A | | 2.0E12 | 5.80E-03 | | | | 1.74E-02 |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | 5.00E-04 | | | 2.50E-03 |
| | | | | | 1.0E5 | | 2.60E-03 | | | 1.30E-02 |
| | | | | | 1.0E6 | | 1.50E-02 | | | 7.50E-02 |
| | | D(1/hFE) | 3.0 A | | 2.0E12 | 3.60E-03 | | | | 1.08E-02 |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | 1.00E-03 | | | 5.00E-03 |
| | | | | | 1.0E5 | | 6.40E-03 | | | 3.20E-02 |
| | | | | | 1.0E6 | | 3.00E-02 | | | 1.50E-01 |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |

Figure 8.    Current Dependence of $h_{FE}$ Limit at M, D, and R
             Levels for One Lot of 2N2920.
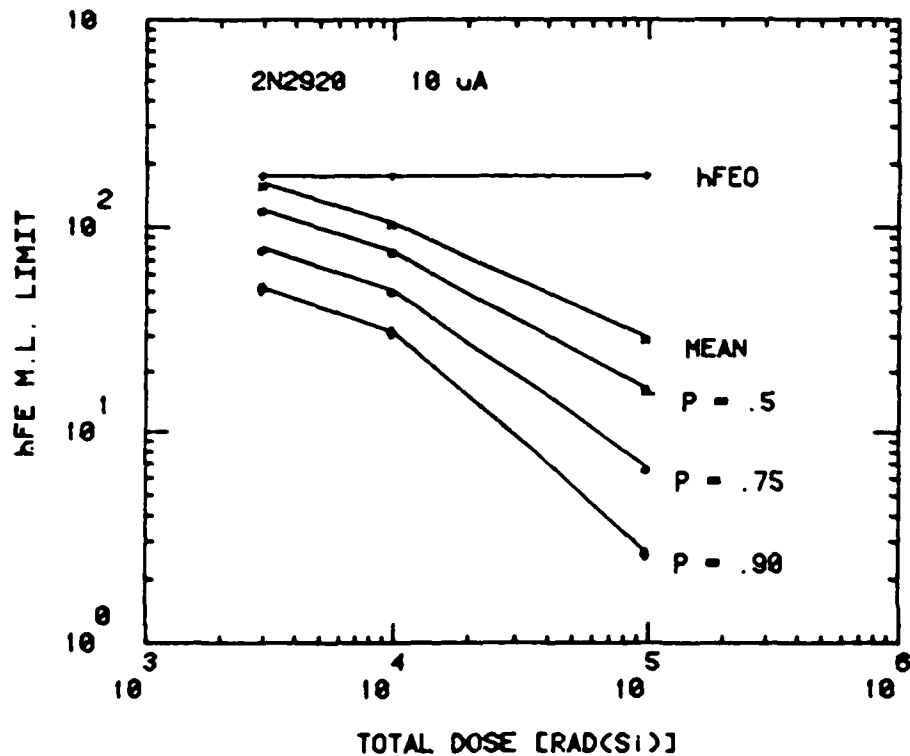


Figure 9.    Multi-Lot Limits for $h_{FE}$ at M, D, and R Levels for
             50%, 75%, and 90% Lot Acceptance Probabilities, 90%
             Confidence for 2N2920.

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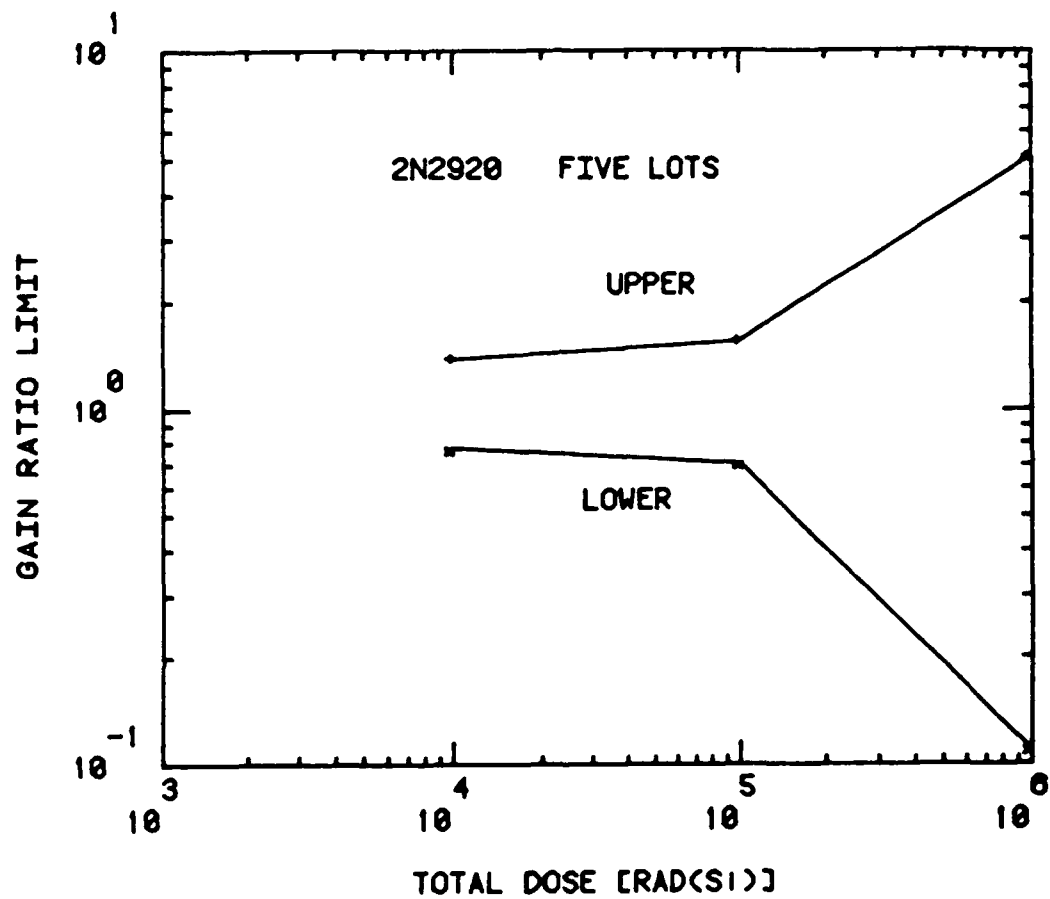
Figure 10    Multi-Lot Limit for Gain Matching Ratio at M, D, and R
Levels for Five Lots of 2N2920.

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low currents requires that a large derating be used if >90 % future lot acceptance is necessary --- an $h_{FE}$ end-point of less than 3 at 100 krads is required. This low $h_{FE}$ is unacceptable for most applications and we must either substantially lower the acceptance probability or restrict the applicable level to lower values. The same situation applies for the gain matching ratio at $10^6$ rad(Si). The 90 percent probability upper and lower limits become impractical. For both of these cases, the end-points must be truncated to a usable value and some degree of vendor/lot selection process will likely occur at R and H levels.

Table 11 is a listing of the sample lots for which radiation characterization data has been analyzed along with their end-point limits.

Table 11.    MULTILOT RADIATION END-POINT LIMIT DATA SUMMARY FOR 2N2920

| | | | | | | 1 | 2 | 3 | 4 | |
| | | | | | | LOT LIMIT | LOT LIMIT | LOT LIMIT | LOT LIMIT | |
| DEVICE TYPE | SLASH NO. | PARAM. | BIAS | PRE-RAD. END-POINT | STRESS | TI 0944 | RAY 1115 | TI 0959 | TI 0948 | END-POINT LIMIT |
|---|---|---|---|---|---|---|---|---|---|---|
| 2N2920 | 355 | hFE2-1 | 100 uA | 1.10 | 2.0E12 | | | | | |
| | | ------- | | | 3000 | | | | | |
| | | hFE2-2 | | | 1.0E4 | 1.17 | 1.02 | 1.26 | 1.07 | (CONT.) |
| | | | | | 1.0E5 | 1.34 | 1.03 | 1.23 | 1.04 | |
| | | | | | 1.0E6 | 2.20 | 1.00 | 1.07 | 2.21 | |
| | | hFE2-1 | 100 uA | 0.90 | 2.0E12 | | | | | |
| | | ------- | | | 3000 | | | | | |
| | | hFE2-2 | | | 1.0E4 | 0.93 | 0.94 | 0.83 | 0.91 | |
| | | | | | 1.0E5 | 0.79 | 0.92 | 0.86 | 0.86 | |
| | | | | | 1.0E6 | 0.59 | 0.98 | 0.94 | 0.21 | |
| | | hFE1 | 10 uA | 175 | 2.0E12 | | | | | |
| | | | | | 3000 | 177 | 171 | | | |
| | | | | | 1.0E4 | 130 | 124 | | | |
| | | | | | 1.0E5 | 50 | 47 | | | |
| | | | | | 1.0E6 | | | | | |
| | | VCE(SAT) | 1mA/100uA | 0.3 Vdc | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |
| | | ICBO | 45 Vdc | 2.0 nA | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | 0.20 | | | 0.21 | |
| | | | | | 1.0E6 | 4.00 | | | 1.20 | |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |
| | | | | | 2.0E12 | | | | | |
| | | | | | 3000 | | | | | |
| | | | | | 1.0E4 | | | | | |
| | | | | | 1.0E5 | | | | | |
| | | | | | 1.0E6 | | | | | |

Table 11.     MULTILOT RADIATION END-POINT LIMIT DATA SUMMARY FOR 2N2920 (cont.)

|  |  |  |  |  |  | 5 | 6 | 3 | 4 |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | LOT LIMIT | LOT LIMIT | LOT LIMIT | LOT LIMIT |  |
| DEVICE TYPE | SLASH NO. | PARAM. | BIAS | PRE-RAD. END-POINT | STRESS | MOT 0774 | T.I./NAT 0946/ | T.I. 0802 | MULTI-LOT LIMIT | END-POINT LIMIT |
| 2N2920 | 355 | hFE-1 ------- | 100 uA | 1.10 max | 2.0E12 3000 |  |  |  |  |  |
|  |  | hFE-2 |  |  | 1.0E4 | 1.08 |  |  | 1.47 | 1.40 |
|  |  |  |  |  | 1.0E5 | 1.16 |  |  | 1.61 | 1.60 |
|  |  |  |  |  | 1.0E6 | 2.20 |  |  | 3.80 | 2.00 |
|  |  | hFE-1 ------- | 100 uA | 0.90 min | 2.0E12 3000 |  |  |  |  |  |
|  |  | hFE-2 |  |  | 1.0E4 | 0.86 |  |  | 0.72 | 0.70 |
|  |  |  |  |  | 1.0E5 | 0.78 |  |  | 0.63 | 0.60 |
|  |  |  |  |  | 1.0E6 | 0.78 |  |  | 0.25 | 0.50 |
|  |  | hFE1 | 10 uA | 175 | 2.0E12 |  | 59 |  |  | 50 |
|  |  |  |  |  | 3000 | 216 |  |  | 78 | 80 |
|  |  |  |  |  | 1.0E4 | 118 |  |  | 45 | 50 |
|  |  |  |  |  | 1.0E5 | 8 |  |  | 12 | 30 |
|  |  |  |  |  | 1.0E6 |  |  |  |  | 15 |
|  |  | VCE(SAT) | 1mA/100uA | 0.3 Vdc | 2.0E12 |  |  |  |  | 0.35 |
|  |  |  |  |  | 3000 |  |  |  |  | 0.35 |
|  |  |  |  |  | 1.0E4 |  |  |  |  | 0.35 |
|  |  |  |  |  | 1.0E5 |  |  |  |  | 0.35 |
|  |  |  |  |  | 1.0E6 |  |  |  |  | 0.50 |
|  |  | ICBO | 45 Vdc | 2.0 nA | 2.0E12 |  |  |  |  | 4 |
|  |  |  |  |  | 3000 |  |  |  |  | 4 |
|  |  |  |  |  | 1.0E4 |  |  |  |  | 4 |
|  |  |  |  |  | 1.0E5 | 4.60 | 0.20 | 1.80 |  | 10 |
|  |  |  |  |  | 1.0E6 | 10.0 | 1.40 | 10.0 |  | 20 |
|  |  |  |  |  | 2.0E12 |  |  |  |  |  |
|  |  |  |  |  | 3000 |  |  |  |  |  |
|  |  |  |  |  | 1.0E4 |  |  |  |  |  |
|  |  |  |  |  | 1.0E5 |  |  |  |  |  |
|  |  |  |  |  | 1.0E6 |  |  |  |  |  |
|  |  |  |  |  | 2.0E12 |  |  |  |  |  |
|  |  |  |  |  | 3000 |  |  |  |  |  |
|  |  |  |  |  | 1.0E4 |  |  |  |  |  |
|  |  |  |  |  | 1.0E5 |  |  |  |  |  |
|  |  |  |  |  | 1.0E6 |  |  |  |  |  |

# SECTION 3
## DNA ADVISORY COMMITTEE SUPPORT

### 3.1      GENERAL

A brief summary of the work performed in support of the DNA Advisory Group on Hardness Assured Devices is reported in this section.   In addition to supporting the Advisory Group in conjunction with the meetings, specific support was provided in the form of reviews of proposed draft RHA device specifications developed by other parties as well as recommendations concerning RHA specifications in general.   Detailed comments were provided on the final draft of TRW's 16K CMOS SRAM RHA Detail Specification, a recommended format for periodic RHA qualification as a means for reducing QCI costs for M- and D-level parts, and a first draft input to the guideline document for preparation of RHA detail device specifications in preparation by Kaman-Tempo.   A brief summary of these are included in the following sections.

### 3.2      REVIEW OF RHA 16K CMOS RAM DETAIL SPECIFICATION

Specific recommendations were submitted on TRW's draft of the RHA detail specification for 16K CMOS RAMs.   The major recommendations were:

1)    The addition of input threshold voltage tests as a precursor to device failure.   Previous studies have shown that there is often a close correlation between degradation in input threshold voltage and total dose functional failure (Ref. 8). This provides a useful screen for "soft" lots which might functionally fail at total dose levels precariously close to the test level.   Many device types require some type of input threshold voltage measurement as part of normal Group A tests. This was not the case for the 16K RAMs and a recommendation was made to add these additional tests.   This recommendation was incorporated into the latest draft.

2)    A recommendation was made to restate the use of the term, "Post-irradiation electrical characteristics".   The definition of this term is presently being reviewed.

3)    A concern about "imprinting" errors was raised for those devices allowed to power-up in a random state for total dose exposures.   However, this concern is not as serious for devices irradiated to a single level such as is the intent for the devices included in /291 (either 100 krads for R or 1 Mrad for H devices).

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## 3.3 PERIODIC RHA QCI PROPOSAL

The present RHA Mil Spec requirements mandate that all RHA devices be qualified and quality conformance inspection be performed for each lot regardless of the technical necessity. This is a particularly acute problem for certain devices with very low RHA requirements; i.e., devices with designed or intrinsic hardness to levels much higher than M- or D-levels (3000 and $1 \times 10^4$ rads, $2 \times 10^{12}$ n/cm$^2$). The rejection of the concept of using existing radiation data for RHA qualification for this situation requires that standardized radiation characterization testing be performed regardless of their hardness margin. A significant cost savings would be achieved if an alternative method to testing every lot for assuring the hardness of these lots.

A proposal was made for an alternative approach which would minimize these costly repetitive tests with only a small increase in risk in accepting "bad" parts. The basic approach that we propose is to require that RHA Qualification testing be performed for RHA QPL listing as is currently required, but with the additional provision that if the parts satisfy a specific hardness margin above the basic requirements, then RHA QCI testing requirements could be relaxed. The margin would be selected such that it would be highly unlikely that these parts would ever fail QCI testing. Annual "requalification" testing only would be required to monitor major shifts in hardness. This approach, especially for widely used devices, would substantially reduce the cost impact of RHA requirements and result in even further cost savings by increasing the utilization and thus availability of RHA devices. The required hardness margin for this "special" Qual was demonstrated in Ref. 2 using the large store of radiation effects data which currently exists for many mature devices and an analysis approach based on projections of long-term parts hardness variations. This approach avoids many of the original objections to the proposed qualification waiver for these devices.

## 3.4 INITIAL RECOMMENDATIONS FOR RHA GUIDELINES

### 3.4.1 General

The format for incorporating Radiation Hardness Assurance (RHA) into Military Device Specifications will be in the form of:

(1) New RHA detail specifications (such as the /291).
(2) RHA amendments to existing Detail Specifications.
(3) RHA supplements to current amendments.
(4) RHA standard military drawings.

Separate end-point parameter limits for neutrons and total dose must be specified, where applicable, in each detail

specification. This approach is required because of the complexities involved in post-irradiation total dose effects and because the facilities for neutron and total dose exposure are usually located in widely separated areas. This concern is not an issue for all device types, e.g., MOS devices are relatively unaffected at M, D, R, and H neutron levels ($2 \times 10^{12}$ n/cm$^2$) because they are majority carrier devices.

### 3.4.2 Post-Irradiation End-Point Limits

The following is a summary of the key issues which need to be considered in determining the "best" values for post-irradiation end-point limits:

(1) Include key Group A parameters _and_ functional tests.

(2) Use existing or new RHA characterization data to determine parameter sensitivity of representative parts. As a minimum, include key parameters in Electrical Characteristics tables.

(3) Use standard Mil-Spec parameter designations and include M, D, R, and H levels for characterization tests.

(4) Characterize parts to failure.

(5) Use appropriate analysis to determine optimum end-point limits reflecting expected lot-to-lot and vendor-to-vendor variations.

(6) Use standard RHA format for tables.

(7) Use Mil Standard test methods.

### 3.4.3 Post-Irradiation Electrical Characteristics

The post-irradiation electrical characteristics are information for a potential user of RHA parts. We recommend extensions to the current tables of electrical characteristics (Tables 1.4-1.5 in Semiconductors and Table 1 in Microcircuits) to provide this information. These characteristics are necessary for the part user and are parameter values based on electrical post-irradiation end-point limits and, possibly, on the radiation characterization tests performed to obtain these end-points.. For RHA parts, the main feature of the recommended addition to these tables is the combined neutron and total dose performance limits reflecting Group E/D test limits. The recommended format is to add these combined values as Table 1.4.1 or 1.5.1 for Semiconductors and Table 1A for Microcircuits. Since this information applies _only_ to the part user, these tables would be totally optional for the preparation of the RHA specification.

The method recommended for combining end-points is to use one of the following two methods:

(1)  Combine deltas as prescribed in Section 2; apply these results to the pre-irradiation characteristic values.

(2)  Use total dose end-point for M, D, R, and H levels; apply delta limit for Subgroup 1 (neutrons) for combined M, D, R, and H characteristics.

## 3.4.4    Overtesting for RHA Devices

The issue of requiring RHA qualification and/or QCI testing at levels above those specified as the general requirements is presently the subject of much debate.   While overtesting is used  extensively in systems'  nuclear survivability  programs, the  major  participants  in the Mil  Spec  system  are  philosophically  opposed to "custom" testing.   A specific  proposal has been outlined in Section 3.3 which provides for relaxed RHA testing  for QCI where a device type is qualified  to  overtest levels.   This proposal has not been accepted as of the date of this report.

## 3.4.5    Radiation Databanks

Previous attempts to utilize existing radiation characterization data for RHA device development were nonproductive  due to a variety of problems,  many of which were due to format and nomenclature  problems.   Most of the data in  these  databanks were  from tests performed in support of specific  programs  or applications.   As expected,  many of the parameters  and  test levels  differed  from test to test.   Limited success  can  be achieved  using interpolation and extrapolation methods to  develop a standard database, but significant errors can be introduced using such methods (Ref. 7).

The  following  specific recommendations are  proposed  to maximize the utility of radiation databanks:

1.  Establish standard data format based on Mil Spec parameters and nomenclature.  Draft RHA specifications provide a standardized format.

2.  Establish basic data matrix for each device type in these databanks such that missing data could be easily identified and the required data defined.

3.  Develop standardized electronic transfer formats.

4.  Apply screen for "reasonableness" of data.

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SECTION 4

SUMMARY AND RECOMMENDATIONS

4.1     SUMMARY

Radiation Hardness Assured supplements to four military device detail specifications have been prepared using radiation characterization data on the six device types included in these specifications. The four RHA specifications (M38510/101, S19500/323, S19500/350, and S19500/355) include provisions for six part types; the 741A, LM101A, LM108A, 2N3251A, 2N3868, and the 2N2920. The major revisions in these draft RHA supplements compared to previous drafts are as follows:

(1)  Group E/D end-points reduced to only key parameters such as those in regular non-RHA characteristics.

(2)  All reference to "QCI waiver" or "overtest" removed from these draft RHA supplements.

(3)  Nominal derating of pre-irradiation end-points beyond multi-lot estimates for degraded parameters.

(4)  Post-irradiation characteristics only for combined neutron and total dose. Footnote added to eliminate vendor liability.

4.2     RECOMMENDATIONS

The primary recommendations that arise from this effort are the obvious need for better radiation characterization testing standards and a definitive guideline for the preparation of RHA device specifications. The major emphasis in current test standards is directed towards the post-total dose recovery problem in MOS (and MOS-like) devices. The devices included in this study are bipolar devices which do not show significant post-irradiation recovery problems. The biggest problem for this study was the lack of standard test conditions, nomenclature, and data storage. These problems largely eliminated the use of highly structured computer data analysis programs for analyzing these data and forced a large amount of "custom" analyses. The availability of a standard guideline for characterizing RHA devices and for storing and analyzing these data would avoid many of these problems. The use of preliminary draft RHA detail specifications would provide specific data requirements for characterization testing and would greatly simplify the preparation of final RHA detail specifications.

# SECTION 5

# REFERENCES

1. I. Arimura, R. A. Kennerud, and O. R. Mulkey, "Hardness Assured Device Specifications", Defense Nuclear Agency Report No. DNA-TR-81-90, 15 July, 1982.

2. I. Arimura, L. Kolb, and O. R. Mulkey, "Hardness Assured Device Specifications for Moderate Radiation Requirements", Defense Nuclear Agency Report No. TR-84-220-V1, 15 November 1985

3. I. Arimura and R. Audette, "Radiation Hardness Assured Device Specifications", Final Report on NRL contract no. N00014-85-C-2077, 15 November 1987

4. MIL HDBK 280, "Neutron Hardness Assurance Guidelines for Semiconductor Devices and Microcircuits", 10 February 1985.

5. MIL HDBK 279, "Total-Dose Hardness Assurance Guidelines for Semiconductor Devices and Microcircuits", 25 January 1985.

6. I. Arimura and A. I. Namenson, "Hardness Assurance Statistical Methodology for Semiconductor Devices", IEEE Trans. Nucl. Sci., NS-30, No. 6, 4322 (1983).

7. A. I. Namenson, "Hardness Assurance and Overtesting", IEEE Tran. Nucl. Sci., NS-29, No. 6, 1821 (1982).

8. I. Arimura, R. A. Kennerud, and L. Kolb, "Hardness Assured Device Specification for 4K X 1 CMOS/SOS Static RAM", Defense Nuclear Agency Report No. TR-84-220-V2, 11 February 1985

## APPENDIX A

## SPECIFICATIONS FOR RADIATION-HARDNESS-ASSURED DEVICES---DRAFT

This appendix contains draft radiation-hardness-assured (RHA) supplements to the four military device detail specifications listed below:

(1)  M38510/101F (types 01, 03, and 04)

(2)  S19500/323B (type 2N3251A)

(3)  S19500/350A (type 2N3868)

(4)  S19500/355C (type 2N2920)

MILITARY SPECIFICATION

MICROCIRCUITS, LINEAR, OPERATIONAL AMPLIFIERS
MONOLITHIC SILICON

PAGE 1


1.1 Scope.   ...Add the following sentence:

"Provision for radiation hardness assurance (RHA) to four
radiation levels is included for device types 01, 03, and 04."

Add the following new paragraph:

"1.2.4  Radiation hardness level.  Radiation hardness levels shall
be as defined in MIL-M-38510."

PAGE 3

Add the following new paragraph:

"3.4.3  Post-irradiation performance characteristics.  The
electrical performance characteristics for which significant
changes occur following exposure to the designated radiation
levels are as specified in table IA and apply at an ambient
temperature of 25°C.  These post-irradiation parameter values
are calculated for the combined neutron and total dose defined
in MIL-M-38510 for these part designations."


PAGE 7

Add to Table II, the following:

"Group E end point electrical
parameters (method 5005)"          See table V    See table V

4.2:   Delete "and D inspections (see 4.4.1 through  4.4.4)."  and
add the following, "and E inspections (see 4.4.1 through 4.4.5)."

TABLE IA.  Post-irradiation electrical characteristics
for RHA devices at $T_A = 25°C$.

| Characterisitics | Symbol | Conditions | RHA Lev | -01 Min | -01 Max | -03 Min | -03 Max | -04 Min | -04 Max | Units |
|---|---|---|---|---|---|---|---|---|---|---|
| Input offset voltage | $V_{IO}$ | $R_S = 50$ | M | -10 | +10 | - 8.0 | + 8.0 | - 9.0 | + 9.0 | |
| | | | D | -25 | +25 | - 8.0 | + 8.0 | -10 | +10 | |
| | | 1/ | R | -30 | +30 | - 8.0 | + 8.0 | -12 | +12 | mVdc |
| | | | H | -105 | +105 | -12.0 | +12.0 | -15 | +15 | |
| Input offset current | $I_{IO}$ | 1/ | M | -100 | +100 | -50 | +50 | - 4.0 | + 4.0 | |
| | | | D | -100 | +100 | -50 | +50 | - 5.0 | + 5.0 | nAdc |
| | | | R | -100 | +100 | -110 | +110 | - 6.0 | + 6.0 | |
| | | | H | -150 | +150 | -210 | +210 | - 8.0 | + 8.0 | |
| Input bias current | $I_{IB}(+)$ | 1/ | M | +1.0 | +400 | - 1.0 | +200 | -0.1 | +70 | |
| | | | D | +1.0 | +500 | - 1.0 | +200 | -0.1 | +135 | nAdc |
| | | | R | +1.0 | +700 | - 1.0 | +450 | -0.1 | +135 | |
| | | | H | +1.0 | +1.2u | - 1.0 | +900 | -0.1 | +135 | |
| Input bias current | $I_{IB}(-)$ | 1/ | M | +1.0 | +400 | - 1.0 | +200 | -0.1 | +70 | |
| | | | D | +1.0 | +500 | - 1.0 | +200 | -0.1 | +135 | nAdc |
| | | | R | +1.0 | +700 | - 1.0 | +450 | -0.1 | +135 | |
| | | | H | +1.0 | +1.2u | - 1.0 | +900 | -0.1 | +135 | |
| Open loop voltage gain (single ended) | $A_{VS(+)}$ | | M | | | | | | | |
| | | | D | | | 40 | | | | |
| | | | R | | | 5 | | | | |
| | | | H | | | | | | | |
| Output short circuit current (positive out) | $I_{OS(+)}$ | | M | | | | | | | |
| | | | D | | | | | | | |
| | | | R | | | | | | | |
| | | | H | | | | | | | |
| | | | M | | | | | | | |
| | | | D | | | | | | | |
| | | | R | | | | | | | |
| | | | H | | | | | | | |
| | | | M | | | | | | | |
| | | | D | | | | | | | |
| | | | R | | | | | | | |
| | | | H | | | | | | | |

1/$V_{IO}$ (ADJ) is not performed on device type 02, case 1 only, or on device type 08 for either case.

PAGE 8

Add the following new paragraph:

"4.4.5 Group E inspection. Group E inspection shall be in accordance with table V of method 5005 of MIL-STD-883 and as follows:

    a.    End-point electrical parameters shall be as specified in table V.

    b.    Radiation hardness assurance exposure method 1019 of MIL-STD-883 conditions:

        (1)  Total dose exposure circuit shown in Figure 8."

Device types 01, 04
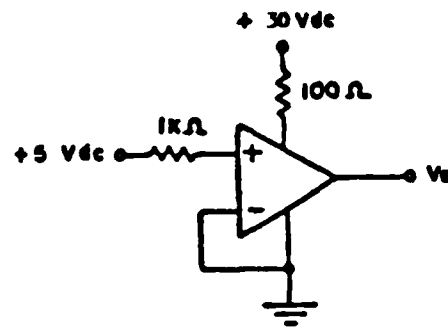


Device type 03



FIGURE 8   Total Dose Exposure Circuit.

TABLE V.  GROUP-E END-POINT ELECTRICAL PARAMETER LIMITS
FOR RHA DEVICES.  $T = 25^{\circ}C$  (all classes).

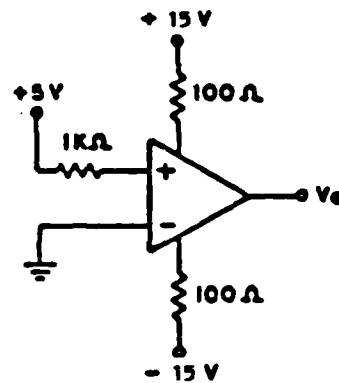| SUBGROUP RHA LEV. | MIL STD 883 | TABLE III TEST NO. | TEST SYMBOL | -01 MIN | -01 MAX | -03 MIN | -03 MAX | -04 MIN | -04 MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1017 | | | | | | | | | |
| NEUTRON | | | | | | | | | | |
| M,D,R,H | | 3 | $V_{IO}$ | -5.0 | +5.0 | -5.0 | +5.0 | -3.0 | +3.0 | mV |
| | | 7 | $I_{IO}$ | -50 | +50 | -20 | +20 | -10 | +10 | nA |
| | | 11 | $+I_{IB}$ | +1.0 | +500 | +1.0 | +120 | -.1 | +10 | nA |
| | | 15 | $-I_{IB}$ | +1.0 | +500 | +1.0 | +120 | -.1 | +10 | nA |
| | | 22 | $I_{OS}(+)$ | -55 | | -55 | | -12 | | mA |
| | | 81 | $A_{VS}(+)$ | 45 | | 45 | | 10 | | V/mV |
| 2 | | | | | | | | | | |
| TOTAL DOSE | 1019 | | | | | | | | | |
| | | 3 | $V_{IO}$ | | | | | | | mV |
| M | | | | -5.0 | +5.0 | -10 | +10 | -4.0 | +4.0 | |
| D | | | | -5.0 | +5.0 | -10 | +10 | -5.0 | +5.0 | |
| R | | | | -20 | +20 | -15 | +15 | -6.0 | +6.0 | |
| H | | | | -100 | +100 | -25 | +25 | -10 | +10 | |
| | | 7 | $I_{IO}$ | | | | | | | nAdc |
| M | | | | -50 | +50 | -20 | +20 | -2.0 | +2.0 | |
| D | | | | -50 | +50 | -20 | +20 | -2.0 | +2.0 | |
| R | | | | -50 | +50 | -175 | +175 | -4.0 | +4.0 | |
| H | | | | -100 | +100 | -380 | +380 | -5.0 | +5.0 | |
| | | 11 | $+I_{IB}$ | | | | | | | nAdc |
| M | | | | +1.0 | +200 | +1 | +100 | -.1 | +60 | |
| D | | | | +1.0 | +300 | +1 | +100 | -.1 | +125 | |
| R | | | | +1.0 | +500 | +1 | +320 | -.1 | +125 | |
| H | | | | +1.0 | +1000 | +1 | +750 | -.1 | +125 | |

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TABLE V.   GROUP-E END-POINT ELECTRICAL PARAMETER LIMITS
FOR RHA DEVICES.   T = 25$^{\circ}$C   (all classes) (cont.)

| SUBGROUP RHA LEV. | MIL STD 883 | TABLE III TEST NO. | TEST SYMBOL | -01 MIN | -01 MAX | -03 MIN | -03 MAX | -04 MIN | -04 MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | | | | | | | | | | |
| | | | | | | | | | | |
| TOTAL DOSE | 1019 | | | | | | | | | |
| | | 15 | $-I_{IB}$ | | | | | | | nA |
| M | | | | +1.0 | +200 | +1 | +100 | -.1 | +60 | |
| D | | | | +1.0 | +300 | +1 | +100 | -.1 | +125 | |
| R | | | | +1.0 | +500 | +1 | +320 | -.1 | +125 | |
| H | | | | +1.0 | +1000 | +1 | +750 | -.1 | +125 | |
| | | 22 | $I_{OS}(+)$ | | | | | | | mA |
| M | | | | -55 | | -55 | | -12 | | |
| D | | | | -55 | | -55 | | -12 | | |
| R | | | | -55 | | -55 | | -12 | | |
| H | | | | -55 | | -55 | | -12 | | |
| | | 81 | $A_{VS}(+)$ | | | | | | | V/mV |
| M | | | | 45 | | 45 | | 20 | | |
| D | | | | 45 | | 45 | | 10 | | |
| R | | | | 45 | | 45 | | 5 | | |
| H | | | | 45 | | 5 | | -- | | |

See footnotes at end of Table I.

MILITARY SPECIFICATION

SEMICONDUCTOR DEVICE, TRANSISTOR, PNP, SILICON, SWITCHING
TYPES 2N3250A, 2N3251A
JAN, JANTX, AND JANTXV

Page 1

1.1   Scope....Add the following:   "Provision for radiation hardness
assurance (RHA) to four radiation levels is provided for JAN, JANTX, and JANTXV
product assurance levels of type 2N3251A".

Add the following new paragraph:

"1.5   Post-irradiation characteristics for RHA devices at 25$^{\circ}$C.*

| RHA LEVEL | LIMITS | HFE1 Vce=-1.0Vdc Ic=-.1mAdc | HFE3 Vce=-1.0Vdc Ic=-10mAdc | HFE4 Vce=-1.0Vdc Ic=-50mAdc | Vce(SAT) Ib=-1.0mAdc Ic=-10mAdc |
|---|---|---|---|---|---|
| M | MIN | 25 | 60 | 20 | |
|   | MAX | | | | 0.30 |
| D | MIN | 25 | 60 | 20 | |
|   | MAX | | | | 0.30 |
| R | MIN | 25 | 60 | 20 | |
|   | MAX | | | | 0.30 |
| H | MIN | 20 | 60 | 20 | |
|   | MAX | | | | 0.30 |

* Post-irradiation characteristics are provided for parts selection purposes
  and are not intended to represent "worst case" application limits.

Page 4

Add the following new paragraphs:

"3.4.1  Radiation hardness level.  Radiation hardness levels shall be as defined in MIL-S-19500."

"4.2.1  Qualification for radiation hardness assurance.  Qualification inspection for RHA JAN, JANTX, and JANTXV devices shall consist of the group D examinations and tests specified in Table V, and in section 4.5.3."


Page 5

Add the following new paragraph:

"4.3.5  Group D inspection.  Quality conformance inspection for RHA JAN, JANTX, and JANTXV devices shall consist of group D examinations and tests specified in Table V and 4.5.3."

Add the following new paragraph:

"4.5.4  Radiation hardness assurance exposure tests.  Conditions for RHA testing shall be according to MIL-STD-750.  For total dose irradiation exposure, Method 1019, the device shall be irradiated with the base and emitter tied together and $V_{CB}$ = -45 Vdc applied."

TABLE V.  Group D inspection for RHA devices (all classes)

| EXAMINATION OR TEST | MIL-STD-750 METHOD | MIL-STD-750 CONDITIONS | QUANTITY/REJECT NUMBER 1/ JANS | QUANTITY/REJECT NUMBER 1/ JAN TX TXV | SYMBOL | LIMITS MIN | LIMITS MAX | UNITS |
|---|---|---|---|---|---|---|---|---|
| Subgroup I | | | | | | | | |
| Neutron Irradiation | 1017 | $25^O$C | 1/ | 1/ | | | | |
| Forward current transfer ratio | 3076 | $V_{CE}$=1.0Vdc $I_C$=0.1mAdc | | | $h_{FE1}$ | | | |
| M,D,R,H2N3251A | | | | | | 70 | | |
| Collector-base cutoff current | 3036 | Bias cond.D $V_{CB}$=40 Vdc | | | $I_{CBO}$ | | | |
| M,D,R,H2N3251A | | | | | | | 40 | nA dc |
| Forward current transfer ratio | 3076 | $V_{CE}$=1.0Vdc $I_C$= 10mAdc | | | $h_{FE3}$ | | | |
| M,D,R,H2N3251A | | | | | | 60 | 300 | |
| Forward Current transfer ratio | 3076 | $V_{CE}$=1.0Vdc $I_C$=50mAdc Pulsed | | | $h_{FE4}$ | | | |
| M,D,R,H2N3251A | | | | | | 27 | | |
| Collector to Emitter voltage (Saturated) | 3071 | $I_C$=10mAdc $I_B$=1.0mAdc Pulsed | | | $V_{CE(SAT)}$ | | | |
| M,D,R,H2N3251A | | | | | | | .30 | Vdc |

TABLE V.  Group D inspection for RHA devices (all classes) (Continued)

| EXAMINATION OR TEST | MIL-STD-750 METHOD | MIL-STD-750 CONDITIONS | QUANTITY/ REJECT NUMBER 1/ JANS | QUANTITY/ REJECT NUMBER 1/ JAN TX TXV | SYMBOL | LIMITS MIN | LIMITS MAX | UNITS |
|---|---|---|---|---|---|---|---|---|
| Subgroup II | | | 1/ | 1/ | | | | |
| Total Dose Irradiation | 1019 | $25^{O}C$ | | | | | | |
| Collector-base cutoff current | 3036 | Bias cond.D $V_{CB}$=40 Vdc | | | $I_{CBO}$ | | | |
| M,D2N3251A | | | | | | | 40 | nA dc |
| R2N3251A | | | | | | | 50 | nA dc |
| H2N3251A | | | | | | | 100 | nA dc |
| Forward current transfer ratio | 3076 | $V_{CE}$=1.0Vdc $I_{C}$=0.1mAdc | | | $h_{FE1}$ | | | |
| M, D, R2N3251A | | | | | | 70 | | |
| H2N3251A | | | | | | 40 | | |
| Forward current transfer ratio | 3076 | $V_{CE}$=1.0Vdc $I_{C}$= 10mAdc | | | $h_{FE3}$ | | | |
| M, D2N3251A | | | | | | 90 | 300 | |
| R, H2N3251A | | | | | | 90 | 300 | |
| Forward Current transfer ratio | 3076 | $V_{CE}$=1.0Vdc $I_{C}$=50mAdc Pulsed | | | $h_{FE4}$ | | | |
| M,D,R,H2N3251A | | | | | | 27 | | |
| Collector to Emitter voltage (Saturated) | 3071 | $I_{C}$=10mAdc $I_{B}$=1.0mAdc Pulsed | | | $V_{CE(SAT)}$ | | | |
| M,D,R,H2N3251A | | | | | | | .30 | Vdc |

1/  Quantity/reject numbers used are taken from MIL-S-19500

DRAFT NO. _____ DATE _____

DO NOT USE FOR ACQUISITION PURPOSES

MIL-S-19500/350A
SUPPLEMENT TO
AMENDMENT 4
10 JULY 1985

MILITARY SPECIFICATION

SEMICONDUCTOR DEVICE, TRANSISTOR, PNP, SILICON, SWITCHING
TYPES 2N3867, 2N3867S, 2N3868, AND 2N3868S
JAN, JANTX, AND JANTXV

Page 1

1.1 Scope. ...Add the following: "Provision for radiation hardness assurance (RHA) to four radiation levels is provided for JAN, JANTX, and JANTXV product assurance levels of types 2N3868 and 2N3868S".

Add the following new paragraph:

"1.5 Post-irradiation characteristics for RHA devices at $T_A = 25^\circ C$.*

JAN, JANTX, and JANTXV 2N3868 and 2N3868S

| RHA LEVEL | LIMITS | HFE2 Vce=2.0Vdc Ic=1.5 Adc | HFE4 Vce=5.0Vdc Ic= 3.0Adc | Vce(SAT)2 IB=1.5 Adc Ic=150mAdc |
|-----------|--------|------|------|-----------|
| M | MIN MAX | 18 | 15 | 1.0 Vdc |
| D | MIN MAX | 18 | 15 | 1.0 |
| R | MIN MAX | 16 | 10 | 1.0 |
| H | MIN MAX | 10 | 5 | 1.2 |

* Post-irradiation characteristics are provided for parts selection purposes and are not intended to represent "worst case" application limits."

Page 2

Add the following new paragraph:

"3.4.2  <u>Radiation hardness assurance (RHA)</u>.  Radiation hardness levels shall be as defined in MIL-S-19500."

Page 5

Add the following new paragraph:

"4.2.2  <u>Qualification for radiation hardness aswsurance</u>.  Qualification inspection for RHA JAN, JANTX, and JANTXV devices shall consist of the Group D examination and tests ⌐pecified in Table V and 4.5.10."

Page 5

Add the following new paragraph:

"4.3.5  <u>Group D inspection</u>.  Quality conformance inspection for hardness assured types shall include the group D tests specified in Table V and 4.5.10."

Page 14

Add the following new paragraph:

"4.5.10  <u>Radiation hardness assurance exposure tests</u>.  Conditions for RHA testing shall be according to MIL-STD-750.  For total dose irradiation exposure, Method 1019, the device shall be irradiated with the base and emitter tied together and $V_{CB}$ = -45 Vdc applied."

TABLE V.   Group D inspection for RHA 2N3868 and 2N3868S (all classes)

| EXAMINATION OR TEST | MIL-STD-750 METHOD | MIL-STD-750 CONDITIONS | QUANTITY/ REJECT NUMBER 1/ JAN TX TXV | SYMBOL | LIMITS MIN | LIMITS MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Subgroup I | | | | | | | |
| Neutron Irradiation | 1017 | $25^{\circ}C$ | 1/ | | | | |
| Collector-emitter cutoff current | 3041 | Bias cond A $V_{EB}$=-2.0 V $V_{CE}$=-60 V | | $I_{CEX}$ | | | |
| M, D, R, and H | | | | | | -1.2 | uA |
| Forward current transfer ratio | 3076 | $V_{CE}$=2.0Vdc $I_C$=1.5 Adc Pulsed (See 4.4.1) | | $h_{FE2}$ | | | |
| M, D, R, and H | | | | | 20 | | |
| Forward Current transfer ratio | 3076 | $V_{CE}$=5.0Vdc $I_C$=3.0 Adc Pulsed (See 4.4.1) | | $h_{FE4}$ | | | |
| M, D, R, and H | | | | | 16 | | |
| Collector to Emitter voltage (Saturated) | 3071 | $I_C$=1.5 Adc $I_B$=150mAdc Pulsed (See 4.4.1) | | $V_{CE(SAT)1}$ | | | |
| M, D, R, and H | | | | | | -0.90 | Vdc |

1/ Quantity/reject numbers used are taken from MIL-S-19500

TABLE V.  Group D inspection for RHA 2N3868 and 2N3868S (all classes) (Cont.)

| EXAMINATION OR TEST | MIL-STD-750 METHOD | MIL-STD-750 CONDITIONS | QUANTITY/ REJECT NUMBER 1/ JAN, TX, TXV | SYMBOL | LIMITS MIN | LIMITS MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Subgroup II | | | 1/ | | | | |
| Total Dose Irradiation | 1019 | $25^\circ$ C | | | | | |
| Collector-emitter cutoff current | 3041 | Bias cond A $V_{EB}=-2.0$ V $V_{CE}=-60$ V | | $I_{CEX}$ | | | |
| M, D, and R H | | | | | | -1.2 -2.0 | uA |
| Forward current transfer ratio | 3076 | $V_{CE}=2.0$Vdc $I_C=1.5$ Adc Pulsed (See 4.4.1) | | $h_{FE2}$ | | | |
| M, D R H | | | | | 27 22 10 | | |
| Forward Current transfer ratio | 3076 | $V_{CE}=5.0$Vdc $I_C=3.0$ Adc Pulsed (See 4.4.1) | | $h_{FE4}$ | | | |
| M, D R H | | | | | 18 12 5 | | |
| Collector to Emitter voltage (Saturated) | 3071 | $I_C=1.5$ Adc $I_B=150$mAdc Pulsed (See 4.4.1) | | $V_{CE(SAT)2}$ | | | |
| M, D R H | | | | | | 0.90 | Vdc |

DRAFT NO. _____ DATE _____

DO NOT USE FOR ACQUISITION PURPOSES

MIL-S-19500/355C
SUPPLEMENT TO
AMENDMENT 1
9 NOV 1984

MILITARY SPECIFICATION

SEMICONDUCTOR DEVICE, UNITIZED DUAL-TRANSISTOR, NPN, SILICON
TYPES 2N2919, 2N2919L, 2N2920, 2N2920L
JAN, JANTX, JANTXV, AND JANS

Page 1

1.1 <u>Scope</u>. ...Add the following: "Provision for radiation hardness assurance (RHA) to four radiation levels is provided for JAN, JANTX, JANTXV and JANS product assurance levels of type 2N2920".

Add the following new paragraph:

"1.6 <u>Post-irradiation characteristics for RHA devices at 25°C</u>.*

JAN, JANTX, JANTXV AND JANS 2N2920

| RHA LEVEL | LIMITS | HFE1 Vce= 5 Vdc Ic= 10uAdc | $h_{FE-1}$ -------- $h_{FE-2}$ Vce= 5Vdc Ic=100 uA | Vce(SAT) IB=100uAdc Ic=1.0mAdc Vdc | Icbo Vcb=45Vdc nAdc |
|---|---|---|---|---|---|
| M | MIN | 30 | 0.8 | | |
|   | MAX | | 1.2 | 0.5 | 6.0 |
| D | MIN | 20 | 0.7 | | |
|   | MAX | | 1.4 | 0.5 | 6.0 |
| R | MIN | 12 | 0.6 | | |
|   | MAX | | 1.6 | 0.5 | 15 |
| H | MIN | 12 | 0.5 | | |
|   | MAX | | 2.0 | 0.5 | 25 |

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* Post-irradiation characteristics are provided for parts selection purposes and are not intended to represent "worst case" application limits."

Page 4

Add the following new paragraphs:

"3.4.1   Radiation hardness level.   Radiation hardness levels shall be as
defined in MIL-S-19500."

Add the following paragraphs:

"4.2.1   Qualification for radiation hardness assurance.  Qualification
inspection for RHA JAN, JANTX, JANTXV, and JANS devices shall consist of
the group D examinations and tests specified in Table V, and in section 4.5.4."

"4.4.4   Group D inspection.  Quality conformance inspection for RHA
JAN, JANTX, JANTXV, and JANS devices shall consist of group D examinations
and tests specified in Table V and 4.5.4."

"4.5.4   Radiation hardness assurance exposure tests.   Conditions for RHA
testing shall be according to MIL-STD-750.  For total dose irradiation
exposure, Method 1019, each device shall be irradiated with their base and
emitters tied together and $V_{CB}$ = 45 Vdc applied to each device."

TABLE V.  Group D inspection for 2N2920 (all classes)

| EXAMINATION OR TEST | METHOD | CONDITIONS | JANS | JAN TX TXV | SYMBOL | MIN | MAX | UNITS |
|---|---|---|---|---|---|---|---|---|
| | MIL-STD-750 | | QUANTITY/ REJECT NUMBER 1/ | | | LIMITS | | |
| Subgroup I | | | | | | | | |
| Neutron Irradiation | 1017 | $25^{\circ}C$ | | | | | | |
| Collector to base cutoff current | 3036 | Bias cond.D VCB= 45Vdc | | | $I_{CBO1}$ | | | |
| M,D,R,H | | | | | | | 4.0 | nA |
| Forward current transfer ratio | 3076 | VCE= 5Vdc IC= 10uAdc | | | $h_{FE1}$ | | | |
| M,D,R,H | | | | | | 50 | 600 | |
| Collector to Emitter voltage (Saturated) | 3071 | IC=1.0mAdc IB=100uAdc Pulsed | | | $V_{CE(SAT)}$ | | | |
| M,D,R,H | | | | | | | 0.4 | Vdc |
| Forward-current transfer ratio | 3076 | $V_{CE}$=5 Vdc $I_{C}$=100 uAdc (see 4.5.4) | | | $h_{FE-1}$ / $h_{FE-2}$ | | | |
| M,D,R,H | | | | | | 0.8 | 1.2 | |

*  See footnotes at end of table.

TABLE V.  Group D inspection for 2N2920 (all classes) (Continued)

| EXAMINATION OR TEST | MIL-STD-750 METHOD | CONDITIONS | QUANTITY/REJECT NUMBER 1/ JANS | JAN TX TXV | SYMBOL | MIN | MAX | UNITS |
|---|---|---|---|---|---|---|---|---|
| Subgroup II | | | | | | | | |
| Total Dose Irradiation | 1017 | 25°C | | | | | | |
| Collector to base cutoff current | 3036 | Bias cond.D VCB= 45Vdc | | | $I_{CBO1}$ | | | |
| M, D | | | | | | | 4.0 | nA |
| R | | | | | | | 10 | |
| H | | | | | | | 20 | |
| Forward current transfer ratio | 3076 | VCE= 5Vdc IC= 10uAdc | | | $h_{FE1}$ | | | |
| M | | | | | | 50 | | |
| D | | | | | | 30 | | |
| R | | | | | | 15 | | |
| H | | | | | | 15 | | |
| Forward-current transfer ratio | 3076 | $V_{CE}$=5 Vdc $I_C$=100 uAdc (see 4.5.4) | | | $h_{FE-1}$ / $h_{FE-2}$ | | | |
| M | | | | | | 0.8 | 1.2 | |
| D | | | | | | 0.7 | 1.4 | |
| R | | | | | | 0.6 | 1.6 | |
| H | | | | | | 0.5 | 2.0 | |
| Collector to Emitter voltage (Saturated) | 3071 | IC=1.0mAdc IB=100uAdc Pulsed | | | $V_{CE(SAT)}$ | | | |
| M,D,R,H | | | | | | | 0.4 | Vdc |

1/  Quantity/reject numbers used are taken from MIL-S-19500